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ESSAYS IN ECONOMIC GEOGRAPHY: CONVERGENCE, INEQUALITIES AND
INNOVATIONS IN THE KNOWLEDGE ECONOMY

BY

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DISSERTATION

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ABSTRACT

My dissertation consists of four papers embedded within the Economic Geography field. The first paper analyzes economic growth and convergence from a time series perspective focusing on regional labor markets. The second paper uses microdata to evaluate what is termed conditional sigma convergence. Finally, the third paper uses innovations, as proxied by patents, and studies determinants of innovation intensity in reference to measures of human capital and economic structure such as the degree of specialization, and competitiveness. Each chapter contains a review of the relevant literature.

The paper entitled “Regional Economic Development and Regional Policies in Colombia”, begins by discussing regional imbalances in the last three decades in Colombia. The paper reviews the process by which Colombia is evolving to a pattern that consists of having a single, large metropolis, in this case Bogotá, a pattern that is typical of the Latin American experience. The paper argues that economic policies have not helped in achieving a more balanced spatial pattern of economic development. Instead, most of the economic policies seem to have worsened the situation as they have privileged the core of the country.

The paper entitled “Stochastic Convergence and Regional Disparities: An Application to Urban Wages in Colombia” develops a model for real wages in Colombian metropolitan areas to evaluate the existence of real wage convergence, as predicted by neoclassical theory. The study employs what is termed "Stochastic Convergence" to evaluate whether real wages are converging or not. The major findings indicate that there exist differences in mean wages across urban areas, which persist

through time even when accounting for differences in living costs. The analysis of stochastic convergence reveals that those differences are not vanishing through time. From a policy perspective, the results found are not encouraging given that the greatest wage disparities are more salient in the more impoverished regions such as the city of Barranquilla in the Caribbean Coast and Pasto in the southern part of the country.

In the paper “Real Wages in Colombia: A Convergence Conditional Analysis: 1984-2009”, the convergence hypothesis is studied from a different perspective than has traditionally been done in Colombia. Previous studies in Colombia have used aggregate or average income, whereas this study uses micro-data and employs hedonic models. It is argued that a model based on micro-data shows more complete results, allowing a more specific interpretation of the determinants in the difference of urban wages.

The results indicate that the wage differentials in urban zones are persistent over time, even when controlling for variation in the cost of living which is used to generate real wages. This raises additional concerns: whether the difference continues after taking into account variables which represent the characteristics of workers (Mincer, 1974), the economic sector (Hewings, 1977), and sample selection bias (Heckman 1979), among others. Once these factors are considered in a hedonic model, the differential of the remaining wages can be interpreted as the existing inequality in wages among urban labor markets in the country.

Results from a Mincer-type model that is used to study the microeconomic determinants of wages, indicate that, after controlling for those determinants in the wage equation, significant differentials remain and in some cases are growing over time. This provides evidence to reject the hypothesis of conditional sigma convergence in real

wages for the principal cities in the country and also points to the existence of regional wage inequalities.

In the paper “Innovation and Geography: an Exploratory Analysis of Patents in the U.S.”, the purpose is to assess the extent to which innovation is affected by the structure of the economy in terms of the industrial specialization, diversity and competition. Innovation is proxied by the number of patents registered in the U.S.. Preliminary analysis of data for the year 2000 reveals that there may be some spatial heterogeneity in the model. Based on that, a Geographically Weighted Regression approach is used to evaluate the space-varying coefficients.

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CHAPTER 1

REGIONAL ECONOMIC DEVELOPMENT AND REGIONAL POLICIES IN COLOMBIA

Abundant empirical evidence at the international level shows a negative relationship between economic growth and inequities. In Colombia large inequalities in the distribution of income have become worrisome, because for about three decades these inequities have been increasing and the most impoverished areas such as Caribbean and Pacific coasts have continue relegated from the attention of central Government policies. What is observed in the Colombian context is therefore an increasing territorial polarization without signs of an improvement in this respect in the last years. Moreover, economic policies seem to have worsened the situation of economic imbalances.

1.1. Introduction

At an international level, regularities in the empirical exercises based on Kuznets' approach have been observed. He proposes that there is a relation of U inverted between the inequalities of a country and its economic growth. According to these propositions, as the level of per capita income grow, inequalities grow and from a certain point, the greatest increases in per capita income are accompanied by a reduction of disparities. In Colombia, these inequalities have increased during the last decades and with them the economic growth and welfare of the population could be affected, since the greater inequalities explain, in part, why big cities, such as Bogotá, have reached unprecedented

importance in the national economy. It is no surprise that Colombia has one of the worst income distributions in the world and for this reason, it is an interesting case to study from a local perspective to delve into the specificities of the Colombian regions.

This chapter seeks to review the economic growth and the evolution of inequalities since the last three decades in the Country. It is conducted an evaluation of, probably the only regional policy that the Colombian government has implemented in the last decades: the decentralization. It is, however, shown that this policy has not contributed to the reduction of disparities. On the contrary, it seems that the majority of the resources transferred from the central government have ended up helping the most prosperous regions. The second section of this chapter reviews the theoretical issues that help understanding the evolution of disparities and economic growth. Third section focuses on the Colombian case with respect to the factors associated to inequalities and regional imbalances. Fourth and fifth sections highlight the role of the central government in terms of regional policies and the low success that this has achieved. The last section concludes.

1.2. Theoretical Perspectives on Economic Growth and Regional Imbalances

Economists have long recognized that knowledge spillovers are one of the main sources of economic growth (Marshall, 1920). According to this framework the growth in some sectors or geographic areas is explained in a great deal for the externalities they receive from the knowledge that other sectors created (Romer, 1986; Lucas, 1988). When the sectors grow from ideas or new knowledge that they do not create by themselves, but

rather they “borrow” from other sectors it is said that the knowledge “spills over” other sectors or becomes an externality. Inspired by these ideas, there has recently been a tremendous development in the empirical literature on the determinants of the growth in cities (Glaeser *et al.*, 1992; Glaeser *et al.*, 1995; Ales and Glaeser, 1995; Black and Henderson, 1999). These theoretical frameworks have highlighted knowledge spillovers as important elements of economic growth, especially in the urban environments where, as opposed to the rural areas, ideas may flow quickly due to more person to person contact. The literature on agglomeration economies pioneered by Marshall (1920) provided explanations of why firms are located in urban areas and one of them argues that it was a result of the search for positive externalities in the form of knowledge spillovers from other firms. In this sense Marshall mentions that:

“When an industry has thus chosen a locality for itself, it is likely to stay there long: so great are the advantages which people following the same skilled trade gets from near neighborhood to one another. The mysteries of the trade become no mysteries; but are as it were in the air”. (Marshall, 1920, p. 225).

Jacobs (1969) is being exceptionally recognized for having started the discussion of why cities provide an environment that facilitates the interchange of ideas and thus, in cities due to the ease of person to person contact, knowledge spillovers and externalities are particularly effective at fostering economic growth. More specifically, recent literature studying determinants of innovative outputs refers to the effects of industrial specialization as Marshall externalities and industrial diversity as Jacobs externalities (Paci and Usai, 1999; Ejermo, 2005).

Along the same lines of the work by Jacobs (1969) it is important to highlight the approach taken by Glaeser *et al.* (1992) who discussed the sources of the technological spillovers and their effect on city growth. This new growth theory is particularly relevant for the study of what makes cities prosper, and is particularly important to understand the growth of the main cities of Colombia, especially that of Bogotá, that has become quite a big economy in comparison with the rest of the Colombian urban areas, and more so, compared to the rural ones.

Studies based on the new economic geography with its emphasis on scale economies have influenced the recent literature on the determinants of economic growth (Krugman, 1991). In particular, Krugman has shown that the interaction between economies of scale and externalities can lead to the agglomeration of economic activity (Krugman, 1998). This agglomeration in turn strengthens urban concentration as this phenomenon may act in a virtuous cycle.

Other theoretical proposals that enrich the growing body of literature on the determinants of city growth have been made by Vernon Henderson, Andrei Shleifer, and Edward L. Glaeser (Glaeser *et al.*, 1992; Glaeser *et al.*, 1995; Ades and Glaeser, 1995; Black and Henderson, 1999). The study by Ades and Glaeser (1995) explores why some cities grow and become excessively large by pointing to two elements, namely trade and circuses. In the case of urban growth in Colombia, these elements can be understood as opportunities and amenities. People migrate to the main cities in the search for job opportunities, education and better welfare conditions. Ades and Glaeser's (1995) study show some facts that may be result of the pulling forces of those elements, such as the

concentration the Argentinean population in Buenos Aires with 35% of the population living in the capital. Along the same lines, 10% of Japanese population lives in Tokyo, 25% of the population in Mexico is concentrated in Mexico City among other examples.

The study by Ales and Glaeser (1995) also highlights some prominent themes. The biggest cities are mainly the capital of the countries. This is the case of Bogotá, the capital of Colombia. The authors also remark the importance of the links to natural resources. The higher the share of labor outside the agriculture the more labor not tied to natural resources and the more people will choose to live in the main urban concentrations.

From a policy perspective Krugman and Livas (1996) argue that protectionism will foster urban concentration due to the fact that with higher import taxes the imports become costly in relation to local products and industries (and thus workers) will locate in big cities to supply for national markets. In this respect Colombia has been no exception. For instance, the import-substitution-industrialization (ISI) policies mainly benefited the central areas of the country, especially those that had cumulated the physical capital originated from the coffee export profits, i.e. the coffee belt. This was not the case of regions such as the Caribbean Coast that were not benefited from ISI policies and, on the contrary, due to its geographical advantage for its localization near the coastline, it would have benefited from an export led growth policy. This region was not part of the core producing areas that were located around Antioquia, Caldas, Quindío, Risaralda and northern part of Cauca Valley.

The growth of the central government has also been an important source of imbalances in regional growth in Colombia. It is quite remarkable that total government expenditures during the first half of the twentieth century reached an average of 5% of the Colombian GDP; by the decade of the nineties this figure had surpassed 20% (Junguito and Rincón, 2004). This tremendous growth has mainly benefited the capital of the country as in this city resides the vast majority of the public bureaucracy, as well as the majority of the firms that sign contracts with the public sector, specially the central government (Bonet, 2003).

Political factors also contribute to shaping the economic imbalances. For instance, factors related to democracy and civil rights have various effects on population concentration. It has been stated that governments protect civil rights from people living in the main urban concentrations, as they are the ones that mainly determine the results of the elections (Ades and Glaeser, 1995). This fact becomes a pulling factor for people in the hinterland that will be then inclined to migrate to cities.

Following previous theoretical propositions, in the Colombian literature there have been studies that link the regional development with the disparities and the convergence hypothesis. Moncayo (2002) presents a comprehensive review of these topics until the year 2002. Barón (2004) shows using various indicators of disparities that departmental differences in per capita product are increasing and are more pronounced during the nineties. Cárdenas (2005) poses that although economic growth has permitted to achieve a little reduction in the income gap between 1970 and 2002, because the ratio

between per capita GDP in Bogotá and that one of Chocó declined, this has not been reflected in the quality of life for people with lower incomes.

In 2006 the CEGA (Center for livestock and agricultural studies) built a series of income, consumption and savings for Bogotá and the so-called “old departments”, allowing to analyze income that actually received the departments (taking into account the transfers and discounting taxes), because up to this point research was carried out using a proxy variable such as the departmental GDP. Bonet and Meisel (2006) tested the convergence hypothesis using the dataset produced by CEGA. Their findings point to a polarization process between Bogotá and the rest of the departments of the country. Using stochastic kernel functions the authors show a highly persistent pattern of disparities, as the ranking in terms of the per capita income remain unaltered during the three decades analyzed.

Gaviria and Gelves (2009) also provide evidence of the highly persistent patterns of income inequalities. The authors also use kernel functions to represent these patterns, but using a long run view as they covered various census data starting from the beginning of the 20th century.

Galvis and Meisel (2010) discuss two dimensions of the economic disparities namely time and space. The authors show that poverty is clustered in space and that this clustering remains through time, which constitutes evidence of the highly persistent pattern of disparities in the country. The authors use the Moran scatter plot to study the clustering patterns of poverty using the unmet basic needs, UBN, index for Colombia. The period covered by the study ranges from 1973 to 2005. The general findings are that

poverty is clustered, the clusters remain in space and time and that this situation provides evidence to propose the existence spatial poverty traps in Colombia. As the economic literature has pointed out that these persistent poverty phenomenon that constitutes poverty traps are characterized by low-income equilibriums (Azariadis, 2006), from a policy perspective it is necessary to think about the presence of an external authority that provides a “big push” to the impoverished areas to help them get out of the poverty trap (Rosenstein-Rodan, 1943; Sachs, 2005).

1.3. Factors Associated to Growth and Disparities in Colombia

Throughout the 20th Century Bogotá’s preponderance was not evident. In fact, Colombia was one of the few Latin American countries whose urban net was not dominated by only one city. In the rest of the Latin American countries, with the exception of Brazil and Ecuador, the importance of industrialization was a factor that fostered the consolidation of the principal city as the center of economic and demographic growth.¹

In countries like Colombia the spectacular population growth of Bogotá, its capital is a matter of concern. In fact, Colombia is going through a process of urban polarization in which the economic disparities between the main cities have been increasing since the last three decades (Galvis and Meisel, 2001). In this context, Colombia seems to have been one of the examples that followed Krugman and Livas’ (1996) argument that trade policies used in many developing countries to promote import substitution industrialization led to the rise of huge metropolis.

¹ This section follows the analysis of Galvis and Meisel (2009)

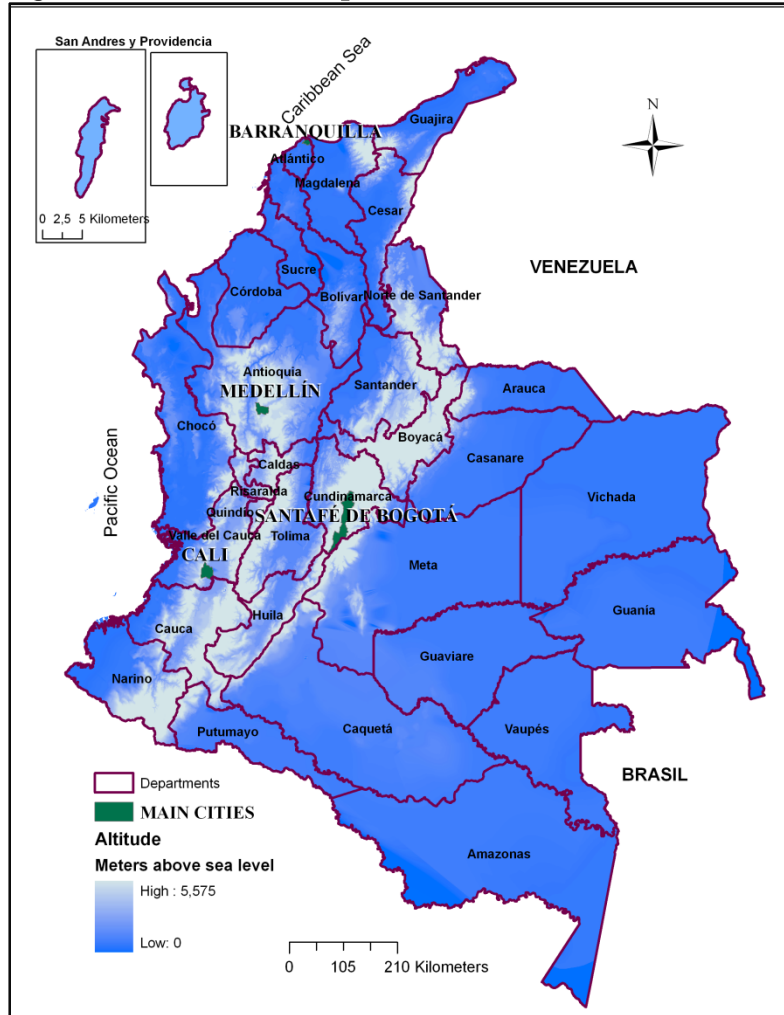
This phenomenon is known as urban primacy, and it appears when the principal city, that have coincided with the country's capital, is overdimensioned in respect to the size of the rest of the cities and a sort of hierarchic dependency is created with the rest of the cities of the urban network. The group of cities begins to depend economically on the principal city, because the most important sources of job opportunities are concentrated in it. The same can be said about the investment and infrastructure that strengthen the capacity to undertake projects and establish new companies and the investment in social and cultural capitals coming from private resources, and also resources of the central government. This way, the middle sized cities turn into net ejectors of populations towards the principal city, which is the one with the largest market and, therefore, the one with the greatest capacity to generate jobs.

In Colombia, urban primacy was not observed earlier, probably because its abrupt topography made land communication relatively deficient between intermediate cities and Bogotá. The latter is already the principal city because of its size and because it is the country's capital.

As a consequence of this result, the localization pattern of the population in Colombia was characterized for presenting several relatively balanced growth poles. This was explained by the country's topography in the sense that, as the Andes mountain range enters though the country's south-west region, it breaks up into three mountain ranges that divide it in several different regions in physical and economic terms. This is how from the mountain ranges emerge the Central Region, with Bogotá as the principal urban center; the Pacific Region, with Cali as the principal urban center; the coffee zone,

with Medellín; and the Caribbean coast, with Barranquilla as the principal city of the region (See Figure 1).

Figure 1. Colombia: Departments and main cities



Source: Prepared by the author based on the map database of the Agustín Codazzi Geographical Institute (IGAC).

1.3.1. Path Dependence: Beginning of the 20th Century

At the beginning of the 20th Century, Bogotá was the only Colombian population with more than 50,000 inhabitants, because the rest of the country was predominantly rural and the settlements were dispersed. One of the effects that industrialization brought

in the following decades was that the four principal cities — in order Bogotá, Medellín Barranquilla and Cali —surged as an urban network.

Notwithstanding, this pattern of an urban network with four fairly balanced cities began to change since the 1950's, when Barranquilla entered a prolonged period of relative economic decline (Posada and Meisel, 1993). As a result Cali became the third city of Colombia and the urban network became dominated by the triangle Bogotá-Medellín-Cali. Later, starting the seventies Colombia has been moving towards the Latin American pattern of urban primacy. Bogotá has been gaining participation in the national population and economy. Already in the census of 1973 its population surpassed the combined population of the three cities that followed it in the number of inhabitants: Medellín, Cali, and Barranquilla. In 1998 the population of Bogotá represented 15.2% of the total Colombian population. Recent projections report that this percentage has surpassed 17%.

In this respect, it is important to mention that Bogotá, according to the 1951 census, represented only 6.2% of the country's population, and, furthermore, only 85% of the aggregate population of the following three principal cities. This means that even though Bogotá was the largest city, it was not overdimensioned in respect to the rest of the principal cities. This is why it is said that the network of cities was relatively balanced.

Each one of these principal cities turned into the economic and industrial center of the most important regions of the country, which, at that time, was relatively segmented: only towards the end of the first half of the 20th Century, these regions began to be

integrated from a net of roads and railways that were built mainly, with the resources obtained as indemnity from the loss of Panama in 1903 and with other resources coming from credits from international institutions (Ramírez, 1999). These funds allowed the country to experiment, during the 1920s to the 1960s, an infrastructure investment phase of unprecedented proportions. This way a road net was consolidated which integrated the main regions of the country, especially those of the Central Zone. These investments were beneficial for the country as a whole, but they also affected the regions in a different way. For instance, the region of the Caribbean coast initially had a privileged position because it had the port of Barranquilla connected to the Magdalena River, the principal means of communication between the region and the center of the country. Nevertheless, that comparative advantage was lost with the preponderance of land transportation and the relatively loss of the importance of river transportation in Colombia. In relation to Panama another element was added to this: the opening of the canal in 1914 gave way so that a couple of decades later, Barranquilla was displaced as the principal loading port consolidating the port of Buenaventura, located on the Pacific coast, but with access now to the Caribbean through the Panamá canal. Because it was closer to Cali, another principal city and because it was better connected with the coffee belt (in relation to Barranquilla), Buenaventura became an important point for the country's business relations with the rest of the world. In effect, coffee, one of the principal products in terms of international market, began to be exported at the beginning of the thirties, mainly from the port of Buenaventura.

Besides the recomposition of the transportation patterns and commercialization of the country's exports, as a consequence of the redefinition of the road infrastructure, with

the importance of coffee in the national economy, the coffee zone consolidated itself as a development and welfare center that sheltered a great part of the country's population. Also, it was a policy goal to turn Colombia into an industrialized country by means of an import substitution policy, which privileged the economy of the coffee region and generated a process of wealth concentration in these zones.

The import substitution policy, at the same time, represented a disadvantage for zones such as the Caribbean coast. The low import taxes of products related with coffee, even with negative rates in real terms, allowed that the coffee zone consolidate itself in the country as the greatest in economic development terms.

1.3.2. The Rise of the Principal Metropolis: Bogotá

When Barranquilla, the principal city in the Caribbean region, and the third in the national context, entered into a process of stagnation and decline the triangle formed by Bogotá-Medellín-Cali became the demographic and economic activity center of the country. Because it was the principal center of economical, financial, demographic, and even political activity, this area, has been frequently referred to as the “golden triangle.” By 1973, almost 20% of the national population was in these three cities, and by 2005, according to census results, this participation reached 26.7%. This change was mainly promoted by the accelerated growth of Bogotá, because in the other principal cities of the triangle, and even in Barranquilla, their participation in the total population was maintained relatively stable (see Table 1).

Table 1. Adjusted population

	1973	1985	1993	2005
Population				
Bogotá	2,530,467	4,236,490	5,484,244	6,778,691
Medellín	1,071,252	1,480,382	1,834,881	2,219,861
Cali	907,090	1,429,026	1,847,176	2,075,380
Barranquilla	656,950	927,233	1,090,618	1,112,889
Total	5,165,759	8,073,131	10,256,919	12,186,821
Participation in the national total				
Bogotá	11.0%	14.5%	15.2%	16.3%
Medellín	4.7%	5.1%	5.1%	5.4%
Cali	4.0%	4.9%	5.1%	5.0%
Barranquilla	2.9%	3.2%	3.0%	2.7%
Total	22.5%	27.6%	28.4%	29.4%
Participation of Bogotá in the aggregate of the following three cities	96.0%	110.4%	114.9%	125.3%
Total Colombia	22,915,229	29,265,499	36,089,725	41,468,384

Source: Prepared by the author based on the census of the National Administrative Department of Statistics (DANE).

In terms of population mobility, in this triangle a very important population dynamics has occurred, because by 1968 all of the cities attracted population and did not expel it, but for the 1993 or the 2005 census, they were net ejectors of population, with the exception of Bogotá, that during all the census periods between 1973 and 2005 it appeared as a net receptor. It calls one's attention that, in the population dynamics, Bogotá is the principal migration destination, including those of the population of the other principal cities which, even though the population of other intermediate cities are adding up, they have an important flow of immigrants towards the capital.

The migration phenomenon has also contributed to the changing pattern of the relatively balanced four principal regions and Bogotá has been consolidating itself as the great metropolis in the national scene. Thus, some geographers have claimed that Colombia is rapidly moving towards the typical Latin American pattern of urban primacy (Gouëset, 1988).

For example, if in 1951 the participation of Bogotá in the aggregate of the three following cities was 85%, in 1973 this amount was 96% and according to the data of the last population census, in 2005 this amount rose to 125%. Some factors that have favored both the economic and the demographic growth of Bogotá have been the agglomeration economies and the great influence of the public sector because it is the seat of the central government. Another reason that has allowed this rise in Bogotá is that it has consolidated itself as the great national market because it is located in the center of the country and is accessible from most of the rest of the country.

As a consequence of those patterns, it is confirmed that since the sixties, Colombia has entered into a dynamic similar to the model of urban primacy, characteristic of Latin American countries, because since then, Bogotá has gained participation in the national total at a rate that the other cities have not been able to match. Also, the principal cities continue having a significant role, but not as much as Bogotá, which in 2007 it sheltered a total of 7.9 million inhabitants, which represented 17.6% of the national population.

The growing importance of capital in the national environment is more notable if one examines the participation of Bogotá in the national GDP: while in 1960 Bogotá contributed with 14% of the GDP, this percentage increased to 24.2% in 1997. It is estimated that in 2007 its participation rose to 25% (De la Cruz, 2010).

Further explanations for the regional imbalances in the economic growth of Colombia were studied by Galvis and Meisel (2001). The authors employ a series of variables to explain the economic growth of cities in Colombia. Among the independent

variables used to explain the rate of growth and level of per-capita GDP it was included those traditionally included in the empirical literature on growth such as human capital and infrastructure. The level of human capital was measured through secondary school attendance as a percent of the relevant population and through the percentage of people who have attended the university in the total population. The physical infrastructure of the cities was measured through the percentage of households that have access to the basic public services (electricity, water, sewage). In the case of the telecommunications variable they used the number of telephone lines per 1000 inhabitants. Other covariates included were several variables related to localization and physical geography. Among the latter there is a variable that measures the altitude above the sea level. The variables related to localization are the distance from Bogotá, the main domestic market, the distance from the seacoast, a dummy variable for the Caribbean region (the poorest region in the country), and a dummy for cities with seaports. The study concludes that the results obtained are consistent with the research of Krugman and Glaeser on regional economics, who emphasized the role of economies of scale and knowledge spillovers to understand the growth of cities, rather than with the recent research of Jeffrey Sachs, that gives special importance to the role of physical geography. On the whole, the variables that constitute fostering factors for economic growth also constitute pulling factors for population growth and Bogotá has either the best, or near the best conditions in terms of those “luring” factors.

Geographic variables may explain localization of people in the country from a historical perspective. Bogotá is located along the Andean mountains and presents an average temperature of 65 Fahrenheit, soil in the surroundings is fertile and the main

endowments in terms of infrastructure are located around it. For the latter fact there is also a historical explanation that goes back to the conquest period as the majority of indigenous population was concentrated around the Andean mountains (Zambrano, 1997). Later the income generated by coffee growers from the Andean was used for investments in communications and infrastructure along the Andean ranges. In this case there is a sort of path-dependence through which the importance of geography in a more agrarian stage of development manifests itself in recent periods and helps in the understanding of the localization of people in the country.

1.3.3. Income Concentration

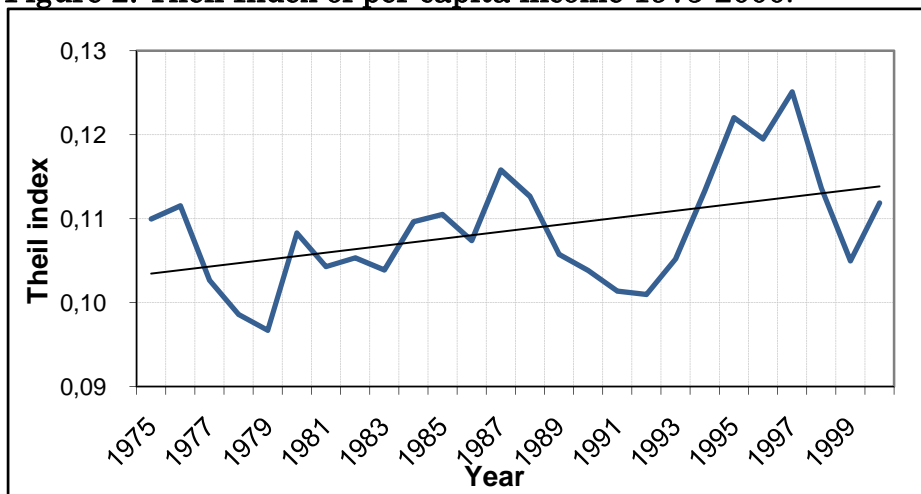
Together with the rising phenomenon of the importance of Bogotá in the national economy, there has been a growing increase in regional disparities in Colombia. This can be seen in the concentration of income per capita in the departments of Colombia, which are the first political-administrative division of the country and in which Bogotá is one of its constituents. Calculations of Theil index of concentration is presented in Figure 2, putting in evidence the polarization in income distribution. Similar results are observed when using the per capita GDP. Note that calculations were made until 2000, the latest date for which data is published for per capita income by CEGA. It is observed that in Colombia territorial units with the highest per capita income in the country have been gaining increasing participation. In turn, the poorest are contributing with a smaller fraction of the income. This has resulted in a series of spatial imbalances in the distribution of wealth in the country, because the most impoverished areas are located in the periphery, mainly along the coast of the Pacific Ocean and Caribbean coast. Within

this coastal zone, for example, despite the fact that it only contributes with 30% of the national population, about 50% of the concentrated population has unmet basic needs (UBN). One would expect that if poverty is equally distributed, territories contributing with 30% of the population participate equally with 30% of people in poverty.

In addition, on the Pacific Coast (defined as the sum of the departments of Chocó, Nariño and Cauca, together with the municipality of Buenaventura), the percentage of people with UBN is 47.9%, and 45.4% on the Caribbean coast, while in Bogotá that percentage was 9.16% in 2005.

If the departments to which cities of the “golden triangle” are added, it is observed that the UBN index in 2005 reached only 15%; a third of what was observed in the Pacific and Caribbean regions.

Figure 2. Theil Index of per capita income 1975-2000.



Source: Author's estimates based on the Center of Livestock and Agricultural Studies (CEGA)

According to these results, it appears that in Colombia the phenomenon of poverty has a clear spatial reference: wealth accumulates in the center of the country and poverty in the periphery. This result is exacerbated because, even within departments, i.e. at the municipal level, disparities are also associated with a spatial phenomenon. There is, for example, a large positive correlation between the distance to the town which is the capital of a department and the proportion of people without basic public services.

In conclusion, in Colombia, the phenomenon of poverty and inequality is present in interdepartmental and intra-regional areas. Unfortunately, national government policies have not been aimed at reducing these disparities. In fact, in recent development plans and government agendas, no policy related to reducing regional economic disparities has been formulated. Moreover, it had already been noted by experts in fiscal policy, that in Colombia the system of allocation of resources from the Government Transfers (GT) and the resources obtained from the exploitation of non-renewable natural resource royalties (NRR) have no explicit mechanisms to compensate for existing regional imbalances (Alesina *et al.* 2000, p. 14).

1.3.4. Regional Labor Market Segmentation

Labor market integration can be achieved through labor mobility in the neoclassical perspective. In this view if supply and demand are not in equilibrium the market will induce changes in prices of the commodity, in other words, wages will adjust to correct those disequilibria in the market. There is another channel of adjustment that will require labor mobility in order to correct the disequilibria and, in some cases, both mechanisms work to yield the equilibrium in the market.

In a country like Colombia it would be expected that the adjustments occur via quantities i.e. through labor mobility as there is little chance for wages to fluctuate according to the market conditions due to certain rigidities in the labor market (Echeverry and Santamaría, 2005). Labor mobility constitutes then a very important element to understand the dynamics of population in a country and the adjustments of the labor market. What determines that mobility? Various factors are counted as determinants with wages being the ones that exhibit an important weight. If labor were perfectly mobile we should observe a national labor market integrated and the equalization of wages across regions would be a reasonable condition to hold.

If we consider a representative market for any product, we could think of the integration in this market as the parity in the prices across regions. The same relationship may hold for the labor market if this is integrated. Why would there be differences in wages across regions? This question can be addressed in the framework of compensating wage differentials across labor markets in which these differentials reflect some desirable and non-desirable attributes associated with a given place of work or occupation. Those characteristics may generate some wage differentials as a form of compensation for the lack of amenities in certain jobs.

First it is important to mention as background previous work such as that of Galvis (2002) who used a gravity-type model to explain the interregional migration in Colombia. The author follows the framework employed by Aroca and Hewings (2001) to show that both the distance and the relative position of the origin and destiny are important for the migration flow. The study concluded that the interregional mobility is

of considerable importance and that the economic conditions of destination and origin regions exert a significant influence on the migration flows. It was shown that, for relatively similar time periods, the net interregional migration rate in Colombia has comparable magnitude to that experienced by countries such as Spain, Ireland, Japan, and the United States which might lead to conclude that the labor market in Colombia is integrated since labor is moving significantly across regional markets, and, therefore, that the wages should be equalized across regions. There are studies, however, that show a different picture of the phenomenon in question. Bonet and Meisel (1999) applied a model of convergence for the period 1929-1995 and found out that per capita income was divergent. Bonet and Meisel used per capita income at departmental level to test the hypothesis of beta convergence without including other covariates that could mediate the process of convergence. Complementary to this study Galvis and Meisel (2001) analyzed the income growth and convergence in per capita income in a sample of twenty of Colombia's largest cities. Those cities comprise more than 50% of the population in the country and the majority of the urban population. The results revealed that per capita income has a divergent trend -unconditional or conditional- and that there exist growing interregional inequalities in income across urban areas.

Previous studies like the one by Nupia (1997) investigated integration in the labor market of the four main metropolitan areas and Jaramillo *et al.* (2001) used urban and rural wages for unskilled workers to study the same issue. Both papers examined average wages of unskilled workers in the regions or metropolitan areas and in that sense the methodology hid important characteristics of the labor and the regional markets that may affect the equalization in wages. I argue that unskilled workers have fewer chances for

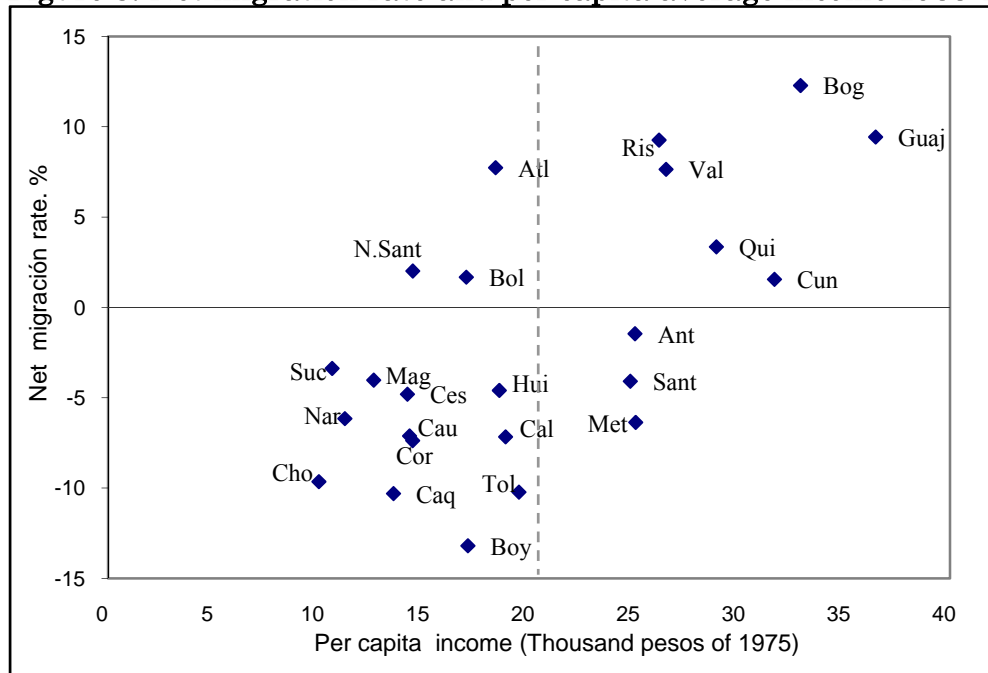
mobility across regions and that element could bias the results of the analysis of market integration. In this sense, considering both unskilled and skilled workers would be a better way to approach the phenomenon of labor market segmentation.

These studies start from the same point of departure supported in the assumption that the difference in prices between two or more markets can be interpreted as evidence of segmentation since neoclassical theory would posit that these differences in prices would vanish due to mobility of factors and goods when the markets are integrated. Consequently, in the labor market, wage differentials might be interpreted as evidence of segmentation as well which in turn may reflect a lack of mobility of labor.

Empirical results have shown that, for instance, Bogotá exhibits the highest magnitudes of wages followed by Cali and Medellín. On the other hand, urban areas that exhibit behaviors that are very dissimilar from the rest of cities are Barranquilla and Pasto. The particularities that are observed in those two cities that may explain the great differential from the other cities are related to the fact that they are located in what it is called the periphery of the country. Because of that, the possibility of movements of labor hand from or to these markets is even more limited.

What makes the results of the imbalances more profound is the fact that the regions that present higher per capita income are the ones who present positive net migration rates (see Figure 3). What is expected is that those departments with higher per capita income, or per capita income above average (right of the dotted line in Figure 3) should be the main population recipients, being those migrants people who move a place where their income could be higher.

Figure 3. Net migration rate and per capita average income 1988-1993.



Note: Vertical dashed line indicates the average per capita income.

Source: Author's calculation.

However, in Romero (2010) it is remarked that in Colombia, internal migration has contributed to human capital concentration in the largest and wealthiest cities, as more qualified people migrate to the main cities. This is support for the hypothesis that the population with more economic resources is the one who can afford mobility across regions.

1.4. Clusters of Poverty the Role of the Central Government

This section discusses spatial autocorrelation indexes in order to assess whether the poverty phenomenon existing in Colombia have a relationship with the spatial framework.

Spatial autocorrelation analysis considers that all phenomena are interrelated in space, but the closest are more correlated than the distant ones. The foundation of this statement derives from the first law of geography or Tobler's law (1970). In this way, for spatial econometric analysis it is of relevance to evaluate statistically the existence of similar values in a variable, occurring in near spaces.

1.4.1. Spatial autocorrelation

Pearson's correlation coefficient has traditionally been used to evaluate the existence of similarity between variables without involving space. This index is defined for X and Z as variables:

$$r = \frac{\sum ZX}{n - 1}$$

This index does not account for similarities in close spaces between the variables which is essential when it comes to variables that are georeferenced, i.e., that have a reference to where the phenomenon occurs in space. In this case it is preferable to use the Moran's I , which parts from the definition of the Pearson correlation coefficient, but adds the location of the observations in the space. This last addition is achieved by including an array of spatial weights, W_{ij} , as follows:

$$I = \frac{N \sum_i \sum_j W_{ij} Z_i Z_j}{S_0 \sum_i Z_i^2}$$

Where $Z_i = X_i - \bar{X}$, i.e. X is in terms of deviations from its mean and $S_0 = \sum_i \sum_j W_{ij}$. The term $W_{ij} Z_i$ is known as the spatial lag of Z . W_{ij} matrix allows us to

identify the "neighbors" of the observations in Z . Based on the “first law of geography” the definition of the neighbors is achieved by building W_{ij} as a binary array whose cells are equal to one, if observations i and j are neighbors, and zero otherwise. Different criteria are used to restrict the neighbors such as contiguity criteria, distance weights, or the K-nearest neighbors.

Since for the calculation of Moran’s I the covariance of Z with its spatial lag, divided by the variance of Z , this can be obtained from the regression of the variable WZ with Z (Anselin, 1996). Thus, if the sign Moran’s I is positive, it is said that there is a positive spatial autocorrelation in the Z variable, i.e. similar values occur in nearby spaces.

Global Moran’s I is useful to detect a general pattern of clustering. However, when it comes to local analysis the Moran’s I index can be used to explore clusters. In this case the analysis is done by means of the Local Indicators of Spatial Association, LISA, which allows for the detection of patterns of spatial autocorrelation in small areas of the study region (Anselin, 1995). For this analysis if Z is set to be a variable resulting from the demeaned X variable, $Z_i = X_i - \bar{X}$, the LISA indicators, I_i , can be built in the following fashion:

$$I_i = \frac{Z_i}{m_2} \sum_j w_{ij} Z_j$$

Where: $m_2 = \sum_i Z_i^2$, which is equal to the variance of the Z variable.

The objective of this analysis is to find matching high values of a variable in a spatial location i as well as in neighboring observations j . This case corresponds to the High-High clusters. Low values in I surrounded also by low values, would correspond to the Low-Low. High-Low and Low-High combinations are also feasible and they would correspond with cases of local outliers. These cases are also of interest as they may indicate a phenomenon of resiliency in the sense that a poor area remains poor without experiencing spillovers to foster wealth coming from the prosperous places in the surroundings.

The inference, the same way as for the Moran's I , is performed by Monte Carlo simulations building a distribution of I_i , to serve as a reference to determine if clusters are statistically significant.

1.4.2. Clusters of Poverty and Transfers from the Central Government

With the decentralization policy strengthened by the Constitution of 1991, and even before it, participations from the national budget were extracted and sent to the territorial units as government transfers, GT. Also, funds were transferred from the exploitation of natural resources (natural resources royalties, NRR) of which a portion should have been allocated to producer municipalities. In addition, a percentage of the NRR should have been divided among other municipalities and departments, following a set of criteria, including, among others, participation in the population.

These funds would be used initially to finance education and health. Only with the last reform of 2007 basic sanitation was included as one of the sectors in which

transferences would be invested. The paradox of these measures is that the very poor provision of basic services such as water and sewage is a source of transmission of diseases that ultimately affect the level of health that, in turn, affect the individual's capabilities to take advantage the education they have received.

It was expected that with such policies, when shifting resources from areas better endowed in terms of natural resources, there would be an impulse to the strengthening of human capital and the reduction of inequalities in available incomes in local government at a disadvantage.

Notwithstanding the foregoing, it is noted that in Colombia the clusters of municipalities where there are large amounts of per capita GT and NRR, do not coincide with clusters of poverty. Figure 4 shows an estimate of spatial clusters of poverty and transfers (GT plus NRR).

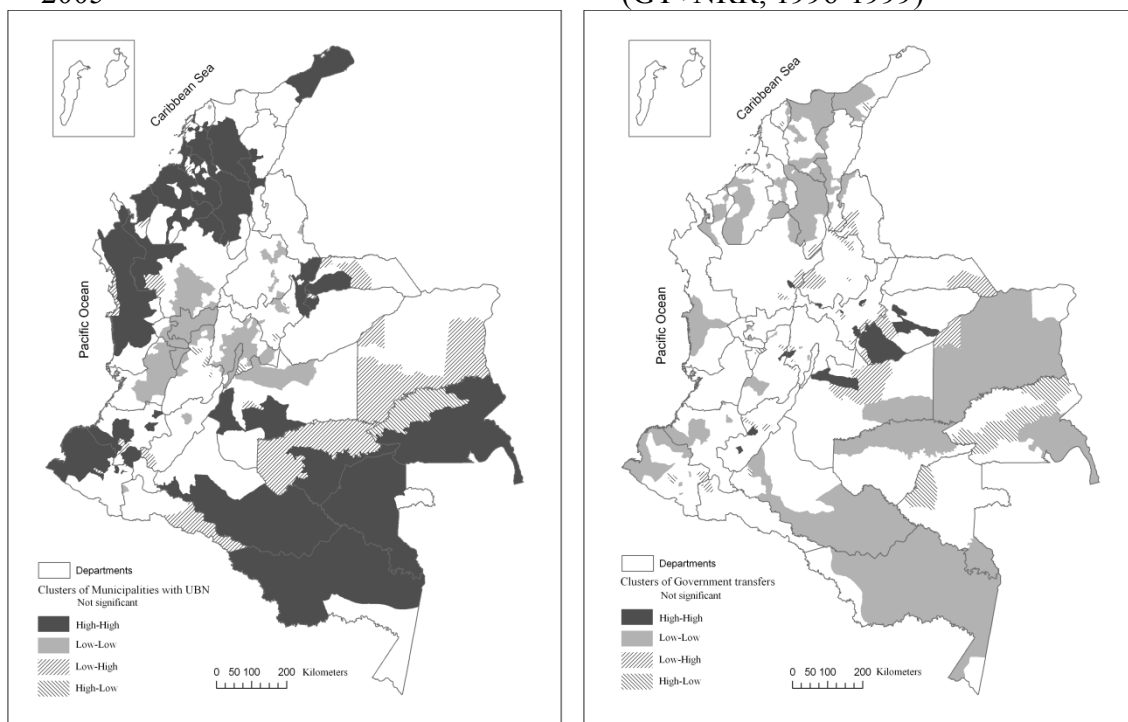
Clusters were identified based on local indicators of spatial association, LISA. The darker shaded areas are the municipalities with high values of the variable in question that are surrounded by municipalities with values significantly high also, called high-high clusters. Consequently the low-low clusters correspond to municipalities with low levels in the measured variable surrounded by municipalities whose value is in the same way, low.

From this analysis we would expect that the high-high clusters in terms of UBN, correspond with areas of higher per capita transfers or high-high clusters. This is not the situation observed and in fact, Panel A in Figure 4 shows that a large fraction of

municipalities with high levels of UBN, are surrounded by municipalities in the same condition without a level of national government transfers corresponding to the situation of poverty (they are located in clusters of low amounts of transfers, represented by gray areas). This happens in the southern part of the departments of the Caribbean coast and in some towns on the Pacific Coast and in several municipalities in the eastern part of the country. Similar results were found for the UBN index for 1993, especially in the Caribbean Coast.

Figure 4. Poverty clusters and transfers from the National Government.

(a) Clusters of municipalities with UBN, 2005 (b) Clusters based on transfers (GT+NRR, 1996-1999)



Source: Prepared by the author based on DANE, the National Administrative Department of Statistics (DANE), the National Planning Department (DNP) and the map database of the Agustín Codazzi Geographical Institute (IGAC).

1.4.3. Trade Policy and Economic Geography

Regarding trade policy, it was assumed that greater trade liberalization in the country in the early 1990's would help reduce regional disparities.

From the point of view of the authorities the mechanism which would act to improve the living conditions in the coastal economies was the location of companies in the areas surrounding ports. This would create jobs and wealth in those areas, the most depressed in the recent history of Colombia. However, the opposite has occurred: the highest concentration of companies in Bogotá and other areas with relatively high wealth, as well as the largest generation of products in these areas has increased disparities. A great deal of companies has preferred to localize in the center of the country to take advantage of a big national market.

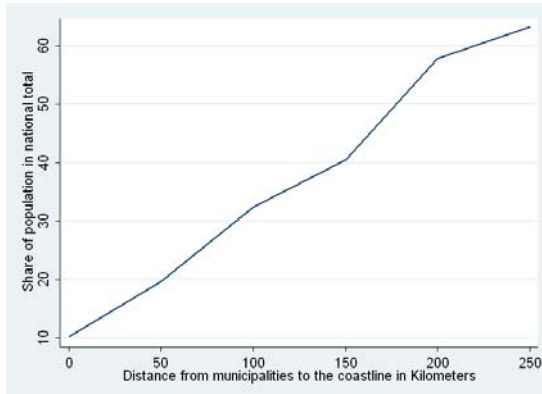
This last result could be expected, according to the approach of the so-called New Economic Geography, NEG: according to Paul Krugman, one would expect that in an economy with high transportation costs, the concentration of economic activity would be localized in the center and not in the periphery.

The expected result of trade liberalization would be that the Colombian economy started resembling an economy such as the US that is more open to trade and, as a stylized fact, shows a great proportion of populous and wealthy cities and Counties around the borders and in the seaports. In Colombia, however this has not occurred as it is shown in Figure 5. This figure portrays the share of population in 2005 living near the coastlines at different buffers of distance. It is shown in Panel A that as one approaches the coastline the share of population decreases. On the other hand, in Panel B it is

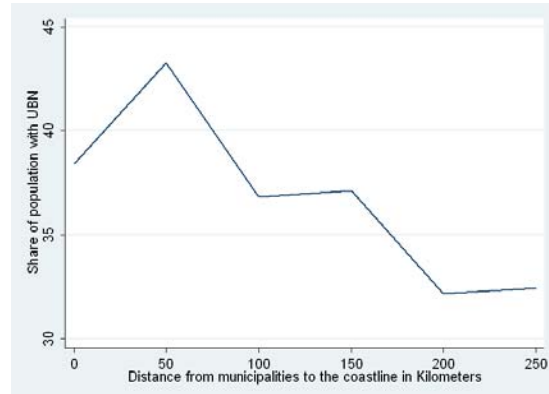
observed that the closer one gets to the coastline, the higher the share of population with UBN (i.e. under poverty conditions).

Figure 5. Relation between distance to the coastline and the share of total population and population with UBN, 2005.

Panel A



Panel B



Source: Prepared by the author based on the National Administrative Department of Statistics (DANE).

On the whole, it seems that decentralization policies and trade liberalization have not been helpful in achieving a more balanced growth in the country's regions.

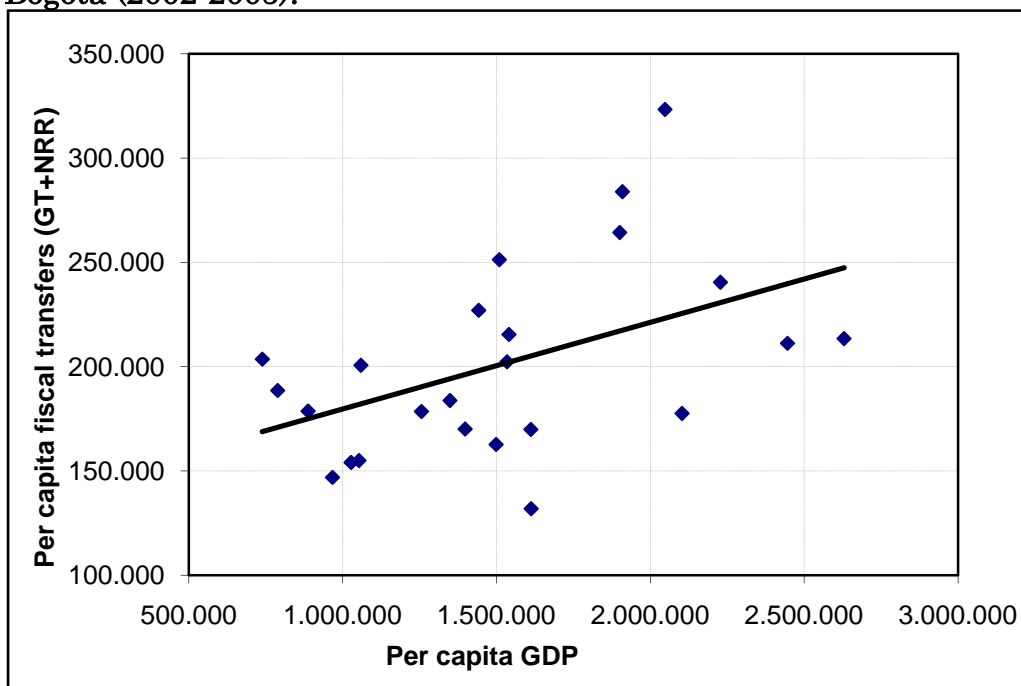
1.5. The Matthew Effect and its Implications in Colombia

It would seem that the policies of the Colombian National Government follow St. Matthew's parable (25:29) closely: "For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath."

It is clear that tax revenues per capita (own revenues plus transfers from the national government) are biased towards less deprived areas, because its income level per capita is above average. This is evident when considering the relationship of departmental per capita GDP and the total per capita income, accounting for what is

received through transfers and what is generated locally. This relation is presented in Figure 6, showing that there is a positive association between the two. This result indicates a clearly regressive policy because the municipalities that have greater per capita wealth are receiving a greater portion of the resources transferred from the central government.

Figure 6. Relation between total tax income per capita, including royalties, and the GDP per capita the departments with their municipalities and Bogotá (2002-2005).



Source: Prepared by the author based on the National Planning Department (DNP) and DANE, the National Administrative Department of Statistics.

It is certainly a priority to define a regional policy that takes into account the elements of fairness, following the example of some developed countries that are more equitable, such as Sweden, and not that of developing and relatively poor countries, with

high levels of inequality. For example, the recent report of the United Nations Development Program (UNDP, 2007) estimates the Gini index, which varies between 0 and 1, with 1 being the highest level of income concentration, and notes that in the global ranking inequalities in income distribution Colombia (with a Gini coefficient of 0.586) is only exceeded by Haiti (0.592), Bolivia (0.601), Botswana (0.605), Central African Republic (0.613), Sierra Leone (0.629), Lesotho (0.632) and Namibia (0.743).

Economic and social policies should seek to reduce the gaps in income distribution which, as discussed above, have a greatly marked regional component. That is, it requires a commitment from the national government to be written into future development plans, taking into account these inequalities and identifying their causes in order to propose strategies to reduce them.

In Colombia, perhaps because it is believed that the market will be the entity responsible for achieving the balance in income distribution policies, clear policies have not been formulated in this regard. However, it is observed that for the segments of the workforce with higher income differentials, such as unskilled labor, they do not tend to equalize over time. This often happens with other qualified segments of labor. One explanation would be that this is the result of the most qualified population groups, or those that are likely to bear the costs of migration, moving to places where the income level is higher.

This phenomenon also has an element that introduces a larger gap in income generation among the territories of the country: if those who are migrating are mostly the most qualified people, and they migrate to areas with better income opportunities, this

labor migration is causing that the most deprived areas lose human capital which could be beneficial to the development of the area they are leaving behind. The portion of the unskilled labor that remains in poorer areas can only access very low-paying jobs.

This migratory phenomenon in Colombia has been characterized by concentrating as the main destinations in order: Bogotá, Cundinamarca, Valle, Antioquia, and Atlántico. To these departments was attracted over 50% of the migration occurred between 1988 and 1993 (Galvis, 2002), according to the 1993 census and between the years 2000 to 2005 according to the 2005 census. Note that these are precisely the departments where wealth is mostly concentrated in the country.

1.6. Concluding Remarks

This document has pointed out to critical issues regarding the regional inequalities in Colombia. It has been shown that the poverty levels that Colombia has reached have been scaling up since a couple of decades. In this regard the natural question to ask is: What has the central government policies done to help improving this situation? The regional policies that the government has implemented to help in this matter seem not to be successful in achieving improvements. On the contrary government transfers have been sent mainly to the most prosperous regions, as there is a positive correlation between per capita income and per capita transfers from the central government.

From another perspective if the regions with the high poverty levels are compared to the places where the main government transfers are allocated, it is found that those impoverished regions are not the ones receiving the higher flow of resources from the

central government. This is clearly a regressive policy as it stands. It does not favor the poorer areas that are mainly rural and located in the periphery of the country.

The questions that remain to be addressed are if the market by itself will solve the problems in the distribution of territorial income. Specifically, is there a trend in the reduction of spatial inequalities in terms of for instance, regional wages? Is it possible to find convergence in regional income, controlling for factors that determine income differentials?

It is important to highlight that if the central government acts according to the Matthew logic, what will be observed in the country in coming years will be a more profound fragmentation between poor and stagnant areas, with no possibility of breaking the cycle of poverty, and thriving and booming areas. The fate of Colombia will be to become a country increasingly polarized in the economic and probably also in the political aspects.

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CHAPTER 2

STOCHASTIC CONVERGENCE AND REGIONAL DISPARITIES: AN APPLICATION TO URBAN WAGES IN COLOMBIA

Abstract

This chapter uses a time series model to evaluate the existence of real wage convergence, as predicted in Neoclassical economic theory, in Colombian Metropolitan areas. While prior work of other investigators focused on β and σ convergence², this study departs from that approach, by using time series models. The aim of this paper is to determine whether real wages are converging, extending previous works by including what has been termed “stochastic convergence”. The main results reveal that when differences exist in wages in urban areas, those differences persist over time even when variations in living costs are taken into account. This result holds for the analysis of the labor market as a whole and for the study of submarkets.

2.1. Introduction and Motivation

Empirical research has identified a negative relationship between initial inequalities and future growth in a cross-section of countries (e.g. Deininger and Squire, 1996). Using cross-section and time series, Persson and Tabellini (1994) and Alesina and Rodrik (1994) showed that higher levels of initial inequality are correlated with

² Beta, β , convergence refers to the case when there is a negative relation between the growth rates and the initial income. Sigma, σ , convergence, on its part, refers to the reduction of dispersion of income.

subsequent lower growth rates. More recently, Engermann and Sokoloff (2002) studied differentials in inequality processes in North America compared to South America and provided evidence for the negative association between inequality and long-run economic growth. This suggests the need for an analysis of whether disparities in income have been increasing, decreasing or remained constant, as they are correlated with income growth as pointed out at the beginning.

In the Neoclassical framework the assumption of factor mobility would provide the conditions for a reduction of disparities as the economies will converge to a steady state where per capita income grows at the rate of the technological change (Solow, 1956). In this framework it is also assumed that poorer countries with low capital-labor ratio will have higher returns to capital, while richer countries with higher capital-labor ratio will experience lower returns to capital. These conditions provide incentives for factors to move between countries until the returns to capital are equalized. Note, however, that factors are more mobile within a country than between countries, as there are barriers for international migration and capital transfers. For this reason, it is expected that, within a country, the differences in returns to factors are reduced more quickly than across countries.

According to this, it is expected that the differential levels in income across regions may even up due to labor mobility, leading to higher levels of income growth in the country, especially between urban areas, where people are more mobile. This hypothesis is neither supported by further studies for urban areas (Galvis and Meisel, 2001) nor for the country as a whole, as shown by Bonet and Meisel (2006).

This paper seeks to address the competing results of the aforementioned studies analyzing per capita income by studying household earnings. This alternative should provide a more comprehensive and accurate view of the disparities in income distribution in the country.

Previous research has analyzed economic growth and convergence in Colombia and has provided evidence both in favor for and against the convergence hypothesis (Moncayo, 2001). This line of research started with the pioneer paper by Cárdenas *et al.* (1993), who provided support in favor of the hypothesis of convergence. Conversely, posterior studies have agreed in rejecting the idea that income is converging towards a similar equilibrium level (see for instance Rocha and Vivas, 1998; Bonet and Meisel, 1999; Galvis and Meisel, 2001); each of them has used different datasets or methods of estimation, and has tested the convergence hypothesis.

Real wages have already been employed in studies of labor market integration in Colombia. Nupia (1997) used real wages for the first time, in a paper analyzing integration in the labor market of the four main metropolitan areas. Subsequently, on Jaramillo *et al.* (2001) used urban and rural wages for unskilled workers to study the same issue of market integration during the period 1945-1998. Galvis (2004) performed an analysis of the main seven metropolitan areas to address the issue of labor market integration including unskilled and skilled workers and differentiating by education level. The paper assumed that highly educated or skilled workers are more mobile than unskilled workers and that an analysis of labor market integration should include both types of workers to be able to draw conclusions about the dynamics of wages in

Colombia. The study concluded that for highly educated workers there is integration into sub-markets, but the same conclusion does not hold for unskilled workers.

The present study builds on previous research going beyond the cross-sectional analysis of convergence and, thus, focusing on convergence from a time series perspective. Again, the purpose of this analysis is to test the convergence hypothesis in real wages and draw conclusions about the behavior of wage disparities. Thus, this analysis focuses on the relationship between wages across regions utilizing the National Household Survey (NHS), conducted for the main metropolitan areas.³ I argue that solely employing unskilled workers gives an incomplete picture of the eventual convergence process because unskilled workers have more limitations on movement between markets and thus their contribution to the wage convergence is more limited than that of the skilled workers. The study is limited to the period 1984-2000 because the NHS was conducted only until 2000. After 2000, the methodology of the household surveys changed. Furthermore, this time frame demarcates an important period of the economy as it encompasses the first decade of the trade liberalization and other economic reforms that were supposed to contribute to the reduction of inequalities in the country. Included were the decentralization policies and the labor reforms that made the labor market more flexible (Kugler, 2000; Echeverry and Santamaría, 2004).

If the labor market reforms were successful in achieving more flexibility in the labor market, it is expected that by the end of the period the wages show a reduction in disparities. This is why a time series framework is more suitable to test for the convergence hypothesis applied to real wages.

³ NHS in Colombia is a survey similar to the CPS that is conducted in the U.S.

The main question underlying this study is twofold: Do significant wage differentials exist across regions and if so, how do they evolve over time? The empirical part of the paper estimates a model at aggregate level using the cointegration methodology applied to average real wages to address this question. It is noted that previous research in the context of Colombia has focused on convergence of per capita income without considering the dynamics through time but has used cross-sectional analysis of convergence (Cárdenas, *et al.* 1993; Bonet and Meisel, 1999; Galvis and Meisel, 2001). Section two of the paper starts by presenting a theoretical framework to analyze the stochastic convergence in real wages. Sections three and four describe the data used for the study and the methodological framework to analyze stochastic convergence. In section five, an analysis of the behavior of wages is presented. The next sections present a series of tests to evaluate the cointegration of regional wages for all the metropolitan areas and for pairs of cities. Finally, section seven presents some discussion and concluding remarks.

2.2. Theoretical Framework

Following the seminal work of Barro and Sala-I-Martin on growth and convergence (1991), empirical literature on the topic has led to new developments and applications throughout the world (for recent reviews see Abreu *et al.* 2005; Islam, 2003). Different frameworks have examined at the convergence in average income or at the reduction of the disparities, but most of the analysis has been focused on cross-sectional designs as opposed to time series modeling.

2.2.1. Convergence in Prices and Parity Purchasing Power, PPP

The difference in prices between two or more markets has traditionally been interpreted as evidence of segmentation. According to neoclassical theory when the markets are integrated, differences in prices would vanish due to mobility of factors and goods. If this prediction from neoclassical theory holds, it should be observed that the differences in wages disappear through time and regional wages should converge to a common equilibrium.

On the other hand, Brown (1980) introduced in the discussion his theory of compensating wage differentials, where he argued for the importance of certain characteristics that make a job more or less desired, such as location, high crime rates, or extreme weather conditions, above and beyond the impact of job and workers attributes on wages.

A related discussion was presented by Roback (1982, 1988), where she stated that wage differences are related to the “amenities” that one place of work or city environment can provide to the worker. In that case, whenever a city has, for instance, high levels of crime, the workers may be attracted to work in that environment provided they receive a higher wage as compensation. Conversely, if a city experiences high living costs, the workers should receive higher compensation as an adjustment.

The analysis of prices between two economies can be carried out through the traditional framework of purchasing power parity (PPP) that is derived from the law of one price to study the idea of wage convergence (Asplund and Friberg, 2000).

The equalization of factor prices can also be related to the Heckscher-Ohlin model in which the increasing interchange in goods and services yields, as a result, equalization in factor prices. In terms of the exchange rate, PPP states that in the long run the prices tend to equalize so that the prices in a domestic economy i , P_i , can be expressed as the product of a nominal exchange rate and external prices, P^e , as follows:

$$P_i = \pi P^e \quad (2.1)$$

Within a country or economy, set the exchange rate among regions is equal to one because the currency is transacted at the same “rate”, i.e., 1. If that relation is expressed in terms of an econometric model by including a stochastic error term a relation between the wages of region i , W_{it} , and those of region j , W_{jt} , will be denoted as:

$$\log W_{it} = \alpha + \beta \log W_{jt} + \varepsilon_t \quad (2.2)$$

Running regressions for this relation will provide evidence of labor market integration in two ways, first by finding a significant relationship between the wages in the two regions and secondly, testing to see whether coefficient β is close to one. The latter condition is more restrictive since it implies that the two series have converged, which is referred to as Stochastic Convergence (Bernard and Durlauf, 1994; Bernard and Durlauf, 1995). In this analysis, the cointegration between the series of wages will imply the existence of a long run equilibrium among them.

Stochastic convergence has been proposed by Bernard y Durlauf (1994, 1995) referring to the empirical work developed for economic growth. Bernard and Durlauf state that, given a set of information \mathfrak{F}_t , in time t , two economies i and j converge if the long run forecast for per capita income tends towards equality:

$$\lim_{T \rightarrow \infty} E[y_i(t+T) - y_j(t+T) | \mathfrak{I}_t] = 0 \quad (2.3)$$

If W_i and W_j denote the wages for region i and j , it is stated that they will follow a common trend if their long run forecast is proportional to each other at time t , given \mathfrak{I}_t :

$$\lim_{T \rightarrow \infty} E[W_i(t+T) - \gamma W_j(t+T) | \mathfrak{I}_t] = 0 \quad (2.4)$$

This way, the cointegration vector is of the form $[1, -\gamma]$. For wages to exhibit stochastic convergence the cointegration vector should be of the form $[1, -1]$.

In the multivariate context the definition of cointegration and stochastic convergence is extended using Johansen's methodology for cointegration (Johansen and Juselius, 1990; Johansen, 1994). Johansen's method overcomes the problems of the single equation analysis where the causality relations are not modeled completely and the exogeneity of the variables is not considered. Using this methodology, it is possible to evaluate the existence of differences in urban real wages and their trend.

In the case of multiple series multivariate cointegration is employed in order to evaluate whether the series are following a long run equilibrium. Stochastic convergence is a particular case of the cointegration relation in which all series are following the same common stochastic trend. This hypothesis will be evaluated by testing whether the number of cointegration vectors, r , is equal to the number of series studied minus one:

$$H_0: r = P - 1 \quad (2.5)$$

If this hypothesis holds, all series are cointegrated and follow a common stochastic trend, i.e. they present stochastic convergence. Note that it is possible to find cointegration between the set of series, but having more than one stochastic trend. For

instance it could be the case that half of the cities are following one stochastic trend e.g. for higher wages, and the rest following a second stochastic trend e.g. for lower wages.

2.2.2. Johansen's Method for Stochastic Convergence

The purpose of this section is to summarize the steps followed to explore the cointegration relationships in real wages. Johansen's methodology (1990, 1994), starts considering a Vector Autoregressive of order k , VAR(k), for a vector of dependent variables, X_t , where:

$$X_t = A_1 X_{t-1} + \dots + A_k X_{t-k} + \Phi D_t + \varepsilon_t \quad (2.6)$$

X_0, \dots, X_{k+1} are vectors fixed variables, A is an $(n \times n)$ matrix of coefficients, and D_t is a vector of exogenous or non stochastic variables whose components could include a constant term, seasonal dummies or indicator dummies to account for qualitative changes in the series. ε_t is a vector of independent residuals such that $\varepsilon_t \sim N(0, \Sigma)$. This type of model may be estimated by OLS without any problems of inconsistency because the right hand side of the equation includes solely lagged or predetermined independent variables (Sims, 1980).

Equation 2.6 is reformulated in terms of what is known as the error correction model, ECM, so that it is possible to have stationary series on the left hand side of the equation, i.e. the first difference of the vector X_t , as well as the lags of that variable on the right hand side. This allows for a representation from which it is possible to obtain the number of cointegration vectors, as follows:

$$\Delta X_t = \Gamma_1 X_{t-1} + \Gamma_2 \Delta X_{t-2} + \dots + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi X_{t-1} + \Phi D_t + \varepsilon_t \quad (2.7)$$

Where $\Gamma_1 = -(I - A_1 - \dots - A_i)$, $i = (1, 2, \dots, k - 1)$ and $\Pi = -(I - A_1 - \dots - A_k)$.

Here the term Π is a matrix of order $(P \times r)$, where P is the number of variables and r is the number of cointegration vectors. Π may be expressed as a product of two matrices, $\alpha\beta'$, where α is the average speed of adjustment from short run to the long run equilibrium and β is a vector that accounts for the long run relation.

The number of linearly independent vectors i.e., the number of cointegration vectors, is given by the rank of the matrix Π . In order to determine the number of cointegration vectors, Johansen proposed two methodologies based on maximum likelihood estimation: the trace test and the maximum eigenvalue.⁴

Johansen's methodology also deals with the presence of deterministic elements such as trend and constant terms in the long run or short run relationships. This in turn determines which type of model is more suitable according to the following distinctions:

Model 1 is the simplest model in which there are no deterministic components. Model 2 considers the existence of a constant in the cointegration vector. Model 3 includes a deterministic trend in the series in levels. Model 4 considers the presence of a deterministic trend in the cointegration vector and Model 5 is the most complex model, i.e., the one with the fewest restrictions since it even allows for a quadratic trend in the series in levels.

Furthermore, an analysis of the stationarity of the series is required in order to assess the existence of a long-run relationship among the series of metropolitan wages. It

⁴ All procedures related to the methodology are programmed in the module CATS under RATS software.

has been argued that stationary series should not be included as part of the model in the tests for cointegration (Engle and Granger, 1987; Suriñach et al, 1995); however, as Harris (1995, p.80) pointed out, if one of the variables is stationary and the number of variables is greater than two, the analysis of Johansen's methodology should lead us to the conclusion that this specific variable must not be in the cointegration vector by using exclusion tests, and therefore, in principle, no problem arises by including such variables in the analysis. In fact Dennis *et al.* (2006) also mention that to find cointegration between non stationary series, it is sufficient to have at least two variables in the system being $I(1)$. For this reason, stationary and non stationary variables can be included in the analysis when the system of seven time series is studied.

2.3. The Data

The analysis is developed using the National Household Survey (NHS) to calculate the average real wage for the period 1984-2000 on a quarterly basis. The data used the seven larger cities of the country, namely, Barranquilla, Bogotá, Bucaramanga, Manizales, Medellín, Cali and Pasto. The geographic context of the study is presented in Figure 7.

The NHS is a survey that is carried out quarterly in the main metropolitan areas by the Colombian National Statistics Office, DANE. This survey includes questions about labor market conditions, a component for unemployed and inactive people, and a component regarding personal information. Some waves of the survey include cities other than the main metropolitan areas but they do not appear every quarter; as a result, they were not included in the analysis.

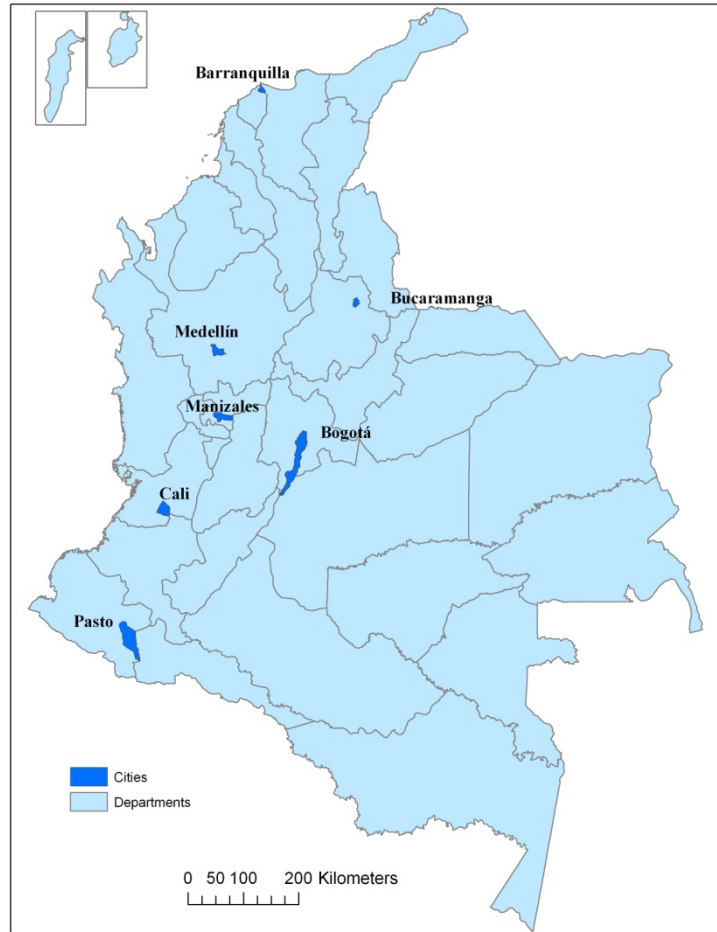
After the year 2000 the NHS was not carried out but was replaced by the Continuous Household Survey, CHS. In the latter, there was a change in the methodology, after which the survey frequency, the sample size and the definition of some variables were modified to follow the recommendations of the International Labor Organization, ILO. These changes make the two surveys not directly comparable for some variables such as unemployment, for instance.

In the models, seasonal dummies are included to deal with the likely seasonality in the behavior of the wages. Seasonal dummies included are centered, i.e. they sum up to zero over time. This condition is included to guarantee that the presence of the deterministic variables does not affect the asymptotic distribution of the tests conducted under Johansen's methodology.

To obtain the nominal wages, it was necessary to calculate the ratio between average monthly income received and the average number of hours worked during a week times the number of weeks per month.⁵ Then the consumer price index was used to deflate the nominal wages to 1988 prices. Since it is possible that some differences in living costs across cities may exist, the price indexes were calculated for each metropolitan area. This procedure in turn helps in following the path adopted by Roback (1982, 1988) who explored living costs and wage differentials across US cities.

⁵ The number of weeks per month used was 4.28. This number resulted from the ratio 30 days per month / 4 weeks per month.

Figure 7. Location of the seven main metropolitan areas



Source: Author's elaboration.

2.4. Behavior of Urban Wages

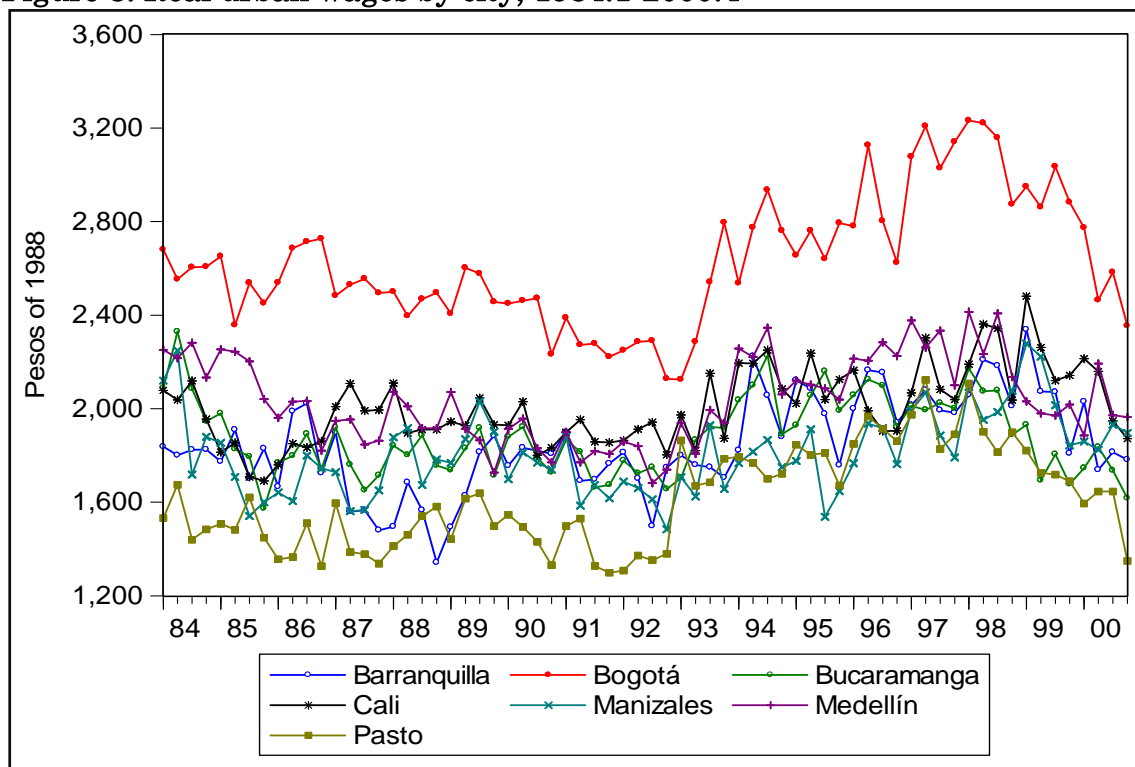
The first approach undertaken to characterize the behavior of urban wages is to analyze their trends over time and explore the patterns revealed.

Figure 8 shows the average hourly wage, at constant prices of 1988 for the seven principal metropolitan areas. The graph shows that Bogotá is the metropolitan area that has experienced the highest wages and it is the area that has deviated the most from the behavior of the rest of the metropolitan areas. On the contrary, the remaining

metropolitan areas present a very similar behavior in wages. For instance, the wages in Cali and Medellín present similar trends and are very close to one another.

In spite of this similar trend, the average wages are clearly different from one city to the next. Equally, it is interesting to note the behavior of the average wage in the city of Pasto, which is maintained during the whole period under the rest of the cities. Because this is probably the city that is most disconnected from the rest of the metropolitan areas, it is very reasonable that the wages have such an atypical behavior.

Figure 8. Real urban wages by city, 1984.1-2000.4



Note: the wages are shown as median income per day expressed in Colombian pesos of 1988.

Source: Calculations of the author based on NHS.

Another feature of note is that the two cities, Bogotá and Pasto, which are located at the extremes in the graph, maintain a gap that has remained stable over the period, which is not true for the rest of the metropolitan areas, which fluctuate with certain

regularity. In fact if the relative wage of the cities compared to Bogotá is estimated, one can appreciate that until 1993, Pasto did not present any pattern that would replicate the behavior of the other cities.

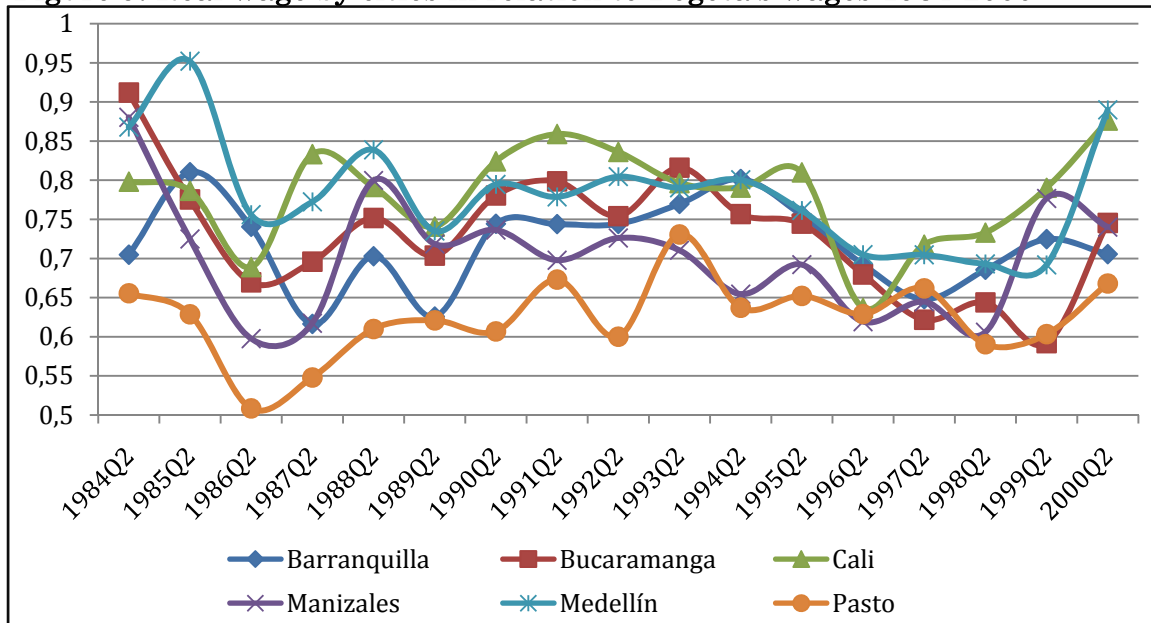
An alternative to the analysis of the deviation of wages across cities is to normalize them by one of the series and observe the resultant behavior. This will allow us to observe whether the series tend to be dispersed or concentrated. This approach is followed by Cecchetti and Sonora (2000) who analyze the behavior of relative prices among the main cities in the United States.

Figure 9 shows the behavior of the wages in Colombia's metropolitan areas of the study in relation to the wages in Bogotá, which is the most important city in the national context. The graph makes evident that overall, the series for most of the cities show a common behavior and a tendency for their dispersion to decrease towards the end of the period.

Figure 9 draws attention to distinctive trends in wages associated with cities located in the periphery such as the case of Pasto that until 1993 remained following its own trend separately from the rest of the metropolitan areas.

It is also observed in Figure 9 that the dispersion of wages is significantly reduced when Bogotá precisely moves away from the rest of the metropolitan areas around 1996. After this year, it is shown a decline in wages in Bogotá which is not followed in the same proportions by the rest of the metropolitan areas and implies that the differential in respect to Bogotá was reduced, mainly towards the end of the period.

Figure 9. Real wage by cities in relation to Bogotá's wages 1984-2000



Note: Data displayed for second quarter of each year.
Source: Calculations of the author based on NHS.

Why have these wage gaps not reduced through time? The analysis now investigates if these difference in wages are reduced when controlling for additional factors that may determine the dissimilar behavior of wages in respect to Bogotá and other important metropolitan areas, such as the existence of local labor sub-markets.

2.5. Empirical Results

2.5.1. Analysis for the National Labor Market

Table B.1 presents the results for the stationarity tests for the wages of the Colombian metropolitan cities included in this study. According to the results, some of the series are stationary but they are included in the cointegration tests as well, following Harris' (1995) argument. According to the graphic analysis performed on the series employed in the empirical exercise, it is reasonable to argue that a quadratic trend is absent in the levels of the series. Moreover, the series show at least the existence of an

intercept in levels and so failing to include any deterministic component would be erroneous. Therefore, model 5 and model 1 of Johansen's methodology are not considered in the analysis.⁶

To evaluate the order of the VAR model, calculations were performed up to a lag k for the first differences of the series. The value for k is determined by minimizing Akaike information criterion, AIC, Schwarz information criterion, SIC, and Hannan-Queen, HQ. As the analysis uses quarterly wage series, the starting values for k were chosen accordingly, including up to 6 lags (i.e. one and a half years lag), above which an effect of the lag on the current wages is not very likely to remain⁷.

The variables used in the tests are introduced in the first differences to estimate the VAR process since this model requires the series to be stationary. Furthermore, to make all the models comparable when choosing the right k , it is necessary to use the same sample for all models considered in the VAR estimation (according to the lag length), to this end, a number of observations are left out as a pre-sample (Lütkepohl, 2005, p.70). It is important to remark the importance of this step because every time one lag is added to the tests, the sample changes, and disregarding this issue may result in wrong values for k (Lütkepohl, 2001).

The results from Information Criteria analyses for lag determination are shown in Table A.1. From this table, the Akaike criterion suggests the choice of the model with six lags while Schwartz and Hannan-Queen criteria chose the model with just one lag. The

⁶ Note that Hansen and Juselius (1995) pointed out that the intercept is needed to take into account the units of measurement in the series and for that reason the use of model 1 is rarely justified.

⁷ Higher lag orders were not significant in any case.

outcome from Table A.1 needs to be taken into account in the cointegration methodology, where a previously determined lag value k is required.

Once it has been specified a value for k , the next step of Johansen's methodology that the present analysis is following, involves choosing the rank of the matrix Π , that is, the number of cointegration vectors. Guided by Akaike Information Criterion, a lag of six periods was used in order to compare various models and take the correct decision about the number of cointegrating vectors, r . To select r , the analysis follows the methodology referred to as the Pantula principle (Johansen, 1992; Harris, 1995), and applies it to the trace and maximum eigenvalue tests shown in Table A.2.

Basically, the Pantula principle consists of reading Table A.2 from the upper left corner to the lower right corner and stopping when it is no longer possible to reject the null hypothesis that the number of cointegration vectors is equal to a specific value r . For instance for lag=1 and a number of cointegration vectors $r=0$, the null hypothesis that $r=0$ is rejected because the calculated value for the trace is 150.05 while the critical value is just 131.7. Thus it is necessary to continue evaluating the next model towards the right side of the table, until the null hypothesis is not rejected.

In the case of $r=1$ the trace calculated is 99.18 and the critical value is 102.14, then the null hypothesis that the number of cointegration vectors is 1, using solely one lag, is not rejected (starred values correspond to the point where the decision regarding the value of r is taken). This is consistent with the result shown earlier by the information criteria in VAR analysis where a lag $k=1$ was selected by Schwartz and Hannan-Queen criteria. Note also that for larger lag values no cointegration vectors were found, since the rejection of the null hypothesis that $r=0$ is not supported.

Johansen's methodology also proposes the maximum eigenvalue test to support the choice of cointegration vectors, r , in a confirmatory analysis fashion. This procedure is used to test the null hypothesis that r cointegration vectors exist, against the alternative hypothesis that $r+1$ exist. The results for the maximum eigenvalue test are presented in Table A.3.

For the eigenvalue method, the number of lags needs to be previously defined. The starting point is determined by looking at the table, as done for the trace test, from the upper left to the lower right direction until the null hypothesis is not rejected. When $r=1$ in the column corresponding to model 2, the test fails to reject the null hypothesis and supports the conclusion that there is one cointegration vector.

The conclusion from this analysis also yields the type of model that is to be used for the next steps of Johansen's methodology. In this case, model 2 was selected. This model considers a constant in the cointegration vector, i.e. a constant in the long run behavior of the series.

It is still required to validate this model in the next step by applying a test for exclusion, which indicates whether the variables present in the cointegration relation have to be included or if, on the contrary, they are redundant. Similarly, if the test fails to reject the null hypothesis that the constant is not significant, then it should be excluded and a different model needs to be chosen.

As for the normality tests, its chi-squared is 11.42, and p-value 0.33. Ljung-Box test for autocorrelation yields a chi-squared test of 406.46 and a p-value of 0.27. According to these results, the tests for normality and autocorrelation indicate desirable

properties of the error terms. Consequently, the conclusions regarding cointegration in the series analyzed so far are sound.

Table A.3 displays the tables employed to carry out the analysis of cointegration. In summary, the trace and the maximum eigenvalue tests coincide in showing that there is one vector of cointegration. According to the stochastic convergence hypothesis, for n number of cities $n-1$ vectors of cointegration are to be found to conclude that all cities are following a long run equilibrium. That is not the case here as there should be at least 6 cointegration vectors. Consequently, as there are cities whose real wages do not follow a long run relation with the others, follows that we reject the stochastic convergence hypothesis is rejected.⁸

So far this paper has dealt with all the metropolitan areas as if they constitute a big national labor market, and the conclusion from the time series analysis results in the rejection of the stochastic convergence hypothesis for this national urban labor market. The question that remains to be addressed is whether when analyzing sub-regions or submarkets the same conclusion is achieved. In this case, the analysis will be carried out by employing pairs of cities.

2.5.2. Local Analysis of Labor Sub-markets

The motivation for the analysis of sub-regional markets originates in the idea that it is possible that functional labor markets operate in the country. Functional labor markets arise when there is commuting across urban areas and the labor market is not defined by physical boundaries but for “commuting boundaries” (Isserman *et al.*, 1986).

⁸ Those cities are assigned a value of N.A. in the panel B of stochastic convergence in Table 3.

To have an idea of the kind of commuting that exists between the cities analyzed, in Table 2 it is shown that the closest cities are Medellín and Manizales, with a physical distance of 164.7 miles, which is a distance a little longer than the commuting distance between Urbana, IL, and Chicago, IL. This distance represents more than three hours of commuting between Medellín and Manizales.

Given that the commuting time between cities is not available, then, in order to obtain this calculation, it is assumed that the trip between the two cities takes place at an average speed of 50 miles per hour. However, for a known route such as Bogotá and Cali, the travel time is approximately nine hours, which makes these calculations a lower boundary for the real time. On top of this, the quality of the roads infrastructure does not guarantee that 50 miles per hour can be achieved during the whole trip. This means that the commuting time could be even longer. This makes it very difficult to suggest that there is a daily commuting between the two cities. However, this does not prevent commuting to occur on a weekly basis.

Table 2. Distances among main metropolitan areas (miles and hours)

		Medellín	Barranquilla.	Bogotá.	Manizales	Pasto	Bucaramanga	Cali
		Miles						
Medellín	H o u r s		471.1	248	164.7	538.2	297.1	283.4
Barranquilla		9.4		612.2	535.7	1,009.3	354.3	754.5
Bogotá		5.0	12.2		172.8	572.4	244.3	317.6
Manizales		3.3	10.7	3.5		433.2	310.8	178.4
Pasto		10.8	20.2	11.4	8.7		779.4	254.8
Bucaramanga		5.9	7.1	4.9	6.2	15.6		524.5
Cali		5.7	15.1	6.4	3.6	5.1	10.5	

Source: calculations of the author based on “Guía de rutas por Colombia, 2010” and INVIAS. Time distance calculated assuming an average speed of 50 miles per hour.

The focus of the rest of the paper is on whether there are pairs of cities that constitute sub-markets for which long run equilibrium exists. This question can be addressed by evaluating the cointegration of wages in a pair-wise fashion as it is presented in Table B.2. The decision regarding the cointegration between the series is presented in Table 3.

Whenever a relation of cointegration is found the hypothesis of stochastic convergence between pairs of cities is tested (panel A in Table 3). The hypothesis of wage parity is assessed by estimating equation 2.2, which amounts to testing whether the coefficient β is equal to one, and if that is the case, then the wages in both cities are stochastically equal to each other. (Panel B in Table 3). This analysis should show us that the cointegration vector $[1,-1]$ yields a stationary relation between wages of the pair of economies analyzed.

This partial analysis should reveal the existence of sub-markets for labor when convergence in wages between a pair of cities is found. As evidenced in Table 3, that is the convergence hypothesis is not supported by the data when analyzing pairs of cities. Some pairs of cities are not cointegrated and the ones that are do not present a convergence process in the real wages.

It is important to note from this result, though, that despite the fact that the analysis does not show the existence of stochastic convergence in wages, there does exist cointegration between pairs of cities such as Cali, Bogotá and Medellín, as well as between Cali and Bucaramanga. The first set of cities has been traditionally identified as the economic engine of the national economy.

Table 3. Evaluation of the stochastic convergence hypothesis in real wages by cities

	Bogotá	Bucaramanga	Cali	Medellin
A. Cointegration				
Bucaramanga	Cointegrated			
Cali	Cointegrated	Cointegrated		
Medellin	Cointegrated	Not Cointegrated	Not Cointegrated	
Pasto	Not Cointegrated	Not Cointegrated	Cointegrated	Not Cointegrated
B. Stochastic Convergence				
Bucaramanga	No convergence*			
Cali	No convergence*	No convergence*		
Medellin	No convergence*	N.A.	N.A.	
Pasto	N.A.	N.A.	No convergence*	N.A.

Note: Barranquilla and Manizales were not included because in the unit roots test this series turned out to be non-stationary.

*: Convergence Hypothesis is rejected at 5% confidence level. N.A.: Not Applicable.

Source: calculations of the author.

This last result is rather controversial since it is at odds with previous evidence for the Colombian labor market. For instance, Nupia (1997), also using a cointegration framework, concluded that the labor market for three main metropolitan areas (Bogotá, Medellín and Cali) is integrated for the period 1976-1995. Later, Jaramillo *et al.* (2001) performed an analysis of integration in the labor market for unskilled labor in urban and rural markets and concluded that the labor market is integrated given that wages are converging for the period 1945-1999. It should be noted that the authors point to some exceptions, such as the city of Barranquilla, which appeared to be segmented from the rest of the urban labor market. This is an important result that calls for further analysis, since the findings of Jaramillo *et al.* (2001) and Nupia (1997) are based on average wages that do not include any control for the type of industry, occupation or personal characteristics, which might affect the dispersion of wages across cities.

I consider that, by and large, the results of the analyses presented thus far clearly point to the notion of a consistent pattern of regional wage differentials across metropolitan areas.

Hereafter, a more comprehensive analysis must be undertaken to explain the sources of this divergence or lack of convergence. The focus should now be on understanding why differentials in wages exist and if they remain after controlling for factors that condition those differentials.

For future work it will be important to consider specific information about the cities to compare the differentials in wages to the city attributes and develop an analysis to explore the possible explanations for the existence of wage differentials. Another important issue to link to this analysis is the industry mix that may determine the availability of jobs in each metropolitan area and the distribution of high and low-pay jobs. This issue is highlighted in the discussion addressed by Hewings (1977). However, employing a structural model to control for amenities or industry mix may have some caveats as there is not enough variability at the city level to capture a significant effect derived from those controls as we only have seven cities or cross-sectional units.

2.6. Concluding Remarks

This study sets off to analyze the convergence hypothesis among the seven main cities in the country, using the National Household Survey data for the period 1984-2000. In contrast to existing research on the topic, this study proposed an alternative analysis in the convergence of income, which gravitates around two main points: The use of real wages as opposed to proxies for income such as per capita GDP, and the analysis taking

into account the full time series, as opposed to cross-sectional data. Results from this alternative perspective lead to the rejection of the hypothesis of convergence in wages in the regions of Colombia.

The proposed methodology, previously described, allow the analysis of real wage behavior through time, which point to the conclusion that there has not been convergence in the urban real wages. Although a relationship of cointegration was found, the analysis of Johansen's methodology did not allow us to draw clear conclusions about the adjustment of all series of wage rate to a long run equilibrium. Even more, some series turned out to be excluded from the long run adjustment, and therefore, the hypothesis of "stochastic convergence" was rejected.

The findings from this study indicate not only the absence of convergence in real wages in Colombia, but more importantly, the persistence of these differences through time.

For future work, I consider it important to further identify specific city attributes driving the wage differential between Colombia's metropolitan areas. Particularly, it would be interesting to emphasize on those factors considered by human capital theory to help explaining regional wage differentials. Similarly, it should be acknowledged that, due to the structure and design of the NHS data, it was not possible to include in the model controls for other variables that might be important in the analysis of wage differentials such as race, union membership and experience.

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CHAPTER 3

REAL WAGES IN COLOMBIA: A CONVERGENCE CONDITIONAL ANALYSIS: 1984-2009

Abstract

Convergence hypothesis has been studied in Colombia employing per capita GDP, income, and per capita bank deposits, among others. This study argues that wages are a more suitable measure for regional income and have a more direct relation to living conditions, than other variables like per capita GDP. In this sense, the study of wages provides a more complete view of disparities and convergence in income distribution. We use Colombian household surveys from 1984 to 2009 to calculate real wages for private sector employees. These data are used to evaluate conditional sigma convergence. Afterwards, we calculate the share of total inequalities, measured by Theil index that can be attributed to interregional disparities. Bootstrapping methods are used to calculate confidence intervals for the interregional component of the Theil index. Results indicate that this component is statistically significant, and that it has not reduced through time. Thus, the findings do not support the convergence hypothesis in this respect. Results from a Mincer-type model that is used to study the microeconomic determinants of wages indicate that, after controlling for those determinants in the wage equation, significant differentials still remain and in some cases are growing over time. This provides evidence to reject the hypothesis of conditional sigma convergence in real wages for the principal cities in the country.

3.1. Introduction

The convergence hypothesis has been studied in Colombia using GDP per capita, income, and banking deposits per capita, among others. Wages in this work are used because they are a better measure of the income in the country's regions and they have a more direct relationship with living conditions than variables such as per capita GDP. This is because departments that are mainly dependent on mining have a per capita GDP above average, but earned income is not necessarily high due to the high participation of the capital in the inputs. Moreover, GDP is not netted out from taxes.

The questions that guided the study are the following: Are there any significant differences in regional wages? If so, how do these differences evolve over time? To answer these questions, this document uses the analysis of micro-data to calculate average wages and estimate the difference among cities. Besides, to capture the difference of wages in each city, fixed effects are included per city, taking Bogotá as a reference. This way, fixed effects represent the average conditional difference in each city in respect to Bogotá. The methodology evaluates if these differentials are maintained after controlling by other factors, which include characteristics of the workers and the sector where they are employed.

This study is different from previous focus such as those of Cardenas *et al.* (1993), Bonet and Meisel (1999), Rocha and Vivas (1998) among others, which were centered in conditioned beta, β convergence, non conditional β and sigma convergence, σ , using per capita GDP. Non conditional β convergence exists when there is a negative relation between the growth rates and the initial income. When this negative relation is found once controlled for the attributes of economies, one talks about

conditional β convergence. Sigma convergence, on its part, refers to the reduction of dispersion of income measured through the variation coefficient or Theil's index, among others.

The objective of this paper is to determine if the real wages are converging, expanding former works through the conditional sigma convergence, seen in time series and cross-sectional data, including controls by the sample selection bias, based in the estimation of hedonic models. Alternate definitions of conditional sigma convergence are proposed, following the distinction used by Barro and Sala-I-Martin (1991) to differentiate conditional β and non conditional convergence.

Some previous studies in Colombia have used aggregate or average income, which result in conclusions which are less detailed than those that can be obtained using a hedonic model. In contrast, a model based on micro-data shows more complete results, allowing a more specific interpretation of the determinants in the difference of urban wages. For example, results indicate that the wages differentials in urban zones are persistent over time, even when controlled by the variation of the cost of life-using real wages. This poses more questions about whether the difference continue being the result of the same forces, or if it changes after including, for example, variables that include the characteristics of workers (Mincer, 1974), the economic sector (Hewings, 1977), sample selection bias (Heckman, 1979, 1980), among others. Once these factors are considered in a hedonic model, the differential of the remaining wages can be interpreted as the existing inequality in the wages through the urban labor markets in the country.

The first part of the document describes the average behavior of wages in the principal cities in the country, and proposes a conditional sigma convergence

measurement evaluating the contribution that the different cities have to wage differentials. For this objective, the paper shows, in the first place, the decomposition of Theil's index, calculating the between and within inequalities using the micro-data of the household surveys. The second part of the study estimates hedonic models that allow the calculation of conditional wage differentials in the regions. It is argued that this focus allows a better understanding of the behavior of the labor market in terms of wage compensation. This section also uses the micro-data of the household surveys to analyze the differences in compensation. For the above, corrections can be implemented for selection bias with Heckman's methodology (1979, 1980), which improves the results in relation to the simple use of the average wages.

3.2. Theoretical and Methodological Framework

3.2.1. Convergence Hypothesis

Since the decade of 1980 there has been a growing interest on the hypothesis of the convergence of the level of income of poorer economies with that of the more prosperous ones (Abramovitz, 1986; Romer, 1986; Lucas, 1988; Barro and Sala-I-Martin, 1990).

Barro and Sala-I-Martin (1990) made one of the most influential contributions to the literature on growth and convergence, both from a theoretical perspective as well as from an empirical one. Their model starts by assuming a Cobb-Douglas production function:

$Y_t = F(K, L) = AK_t^\beta L_t^\alpha$; where Y is the product and K and L are capital and labor factors, respectively. β and α are elasticities of the product with respect to production factors.

This production function is assumed to experience an increasing marginal productivity of factors but at a decreasing rate, such that:

$$\partial Y / \partial L > 0 ; \partial^2 Y / \partial L^2 < 0 ; \partial Y / \partial K > 0 ; \partial^2 Y / \partial K^2 < 0 ;$$

It is also assumed that the production function has constant returns to scale, thus: $F(\lambda K, \lambda L) = \lambda \cdot F(K, L)$, $\forall \lambda > 0$. This condition allows us to express the product as a function of the capital-labor ratio:

$Y = F(K, L) = L \cdot F(K/L, 1) = L \cdot f(k)$, where we can simplify the latter expression to:

$$y = f(k).$$

Where the new term y is per-capita production and k is the capital-output ratio. The labor force, L , is assumed to be fully employed and growing at a constant rate, n , such that: $\dot{L}/L = n \geq 0$.

A fraction of the product that is determined exogenously, $s(^{\circ})$, is saved. This refers to the marginal propensity to savings, s , where $0 \leq s \leq 1$.

In this model, capital depreciates at a constant rate of δ , and thus, the net investment is equivalent to the net increase in the physical stock of capital after discounting depreciation:

$$\dot{K} = \Delta K = I - \delta K = sY - \delta K$$

This last equation can be expressed in per-capita terms as follows:

$$\dot{K}/L = s \cdot f(k) - \delta \cdot k.$$

Where \dot{k} in the previous equation is the rate of change of the capital output ratio:

$\dot{k} = d(K/L)/dt = (\dot{K}/L) - n \cdot k$; which may be rewritten as:

$$\dot{k} = s \cdot f(k) - (n + \delta) \cdot k$$

From this last expression the rate of growth of k per worker, γ , is obtained by dividing both sides by k , which yields:

$$(\dot{k}/k) = \gamma = s \cdot (f(k)/k) - (n + \delta).$$

constant at a level k^* and the economy will approach to what is known as the steady state.

Because of the assumption that the marginal productivity of capital falls as it increases, the dynamic behavior of γ can be expressed as follows:

$$\partial \gamma / \partial k = s/k \cdot [f'(k) - f(k)/k] < 0$$

Convergence hypothesis originates from the dynamic behavior of γ , that can be understood as an inverse relationship between the level of capital and its rate of growth. In other words, poorer economies will grow faster than richer economies. This relationship is expressed in terms of the per capita GDP by formulating:

$$\left(\frac{1}{T}\right) \log \left(\frac{Y_t}{Y_0}\right) = \alpha - \log(Y_0) \cdot \left[(1 - e^{-\beta T}) \cdot \left(\frac{1}{T}\right)\right] + \varepsilon_t \quad (3.1)$$

Where T is the time period, Y_0 and Y_t are, respectively, the initial GDP and the GDP at the end of the period.

In the last expression β represents the rate at which the economy approximates the steady state, that is, the speed of convergence. Absolute convergence holds if the sign of the β coefficient is positive. If the β coefficient is negative there is divergence in per-capita GDP. It must be stressed that absolute convergence makes sense when all the countries or regions in a sample are approximating to a similar steady state. When this is not the case, the analysis refers to the hypothesis of conditional convergence. This hypothesis poses that the approximation to the steady state will hold conditional on other variables that affect the growth process.

More importantly, although the presence of β convergence is a necessary condition for the reduction in disparities in per-capita GDP, it is not a sufficient condition. It is the sigma, σ , convergence that tells us if the dispersion is increasing or not. The σ coefficient is often estimated by the coefficient of variation of per-capita GDP.

In the empirical literature Barro and Sala-I-Martin's work on growth and convergence has inspired a large number of applications (Barro, 1991; Barro and Sala-I-Martin, 1991; Neven and Gouyette, 1995; Carlino and Mills, 1993, Bernard and Jones, 1996, Rey and Montouri, 1999). Different methodologies have evaluated beta convergence in the average income or the reduction of disparities by means of the sigma convergence.

The literature on integration of the labor market and convergence has pointed out the price difference between two or more markets as evidence of segmentation. Dickie and Gerking (1988) pose two possibilities for income convergence. In the first place, the strong convergence in which the non conditional mean wages or income converge among regions; weak convergence, on the other hand, corresponds to the case where the median

conditional (controlling by determining attributes of differentials) converges among regions. Different studies show that strong convergence is generally not observed; such is the case of Dickie and Gerking (1988) for Canada, Blackaby and Manning (1990) for the United Kingdom, and Montgomery (1992) for the North American economy.

“Strong” convergence is related with the concept of sigma convergence. In our case, we will refer to the unconditional sigma convergence in this respect. “Weak” convergence is approached in this study from the definition of conditional sigma convergence. With this concept we will refer to the reduction of disparities controlling by additional factors, to analyze convergence. This point follows the logic of Barro and Sala-I-Martin (1991) with the differentiation between conditional and unconditional beta convergence.

The first focus to approach conditional sigma convergence consists in calculating the participation of interregional inequalities in total inequalities. This procedure takes place with the decomposition of Theil’s index in its interregional and intraregional components.

3.2.2. Conditional Sigma Convergence

The analysis of inequalities among regions is accomplished through the decomposition of Theil’s index in its intra and interregional components, following the spatial decomposition used by Rey (2001). The decomposition of Rey’s index is given by the expression of a G number of groups or cities, as:

$$T = \sum_{g=1}^G s_g \log \left(\frac{n}{n_g s_g} \right) + \sum_{g=1}^G s_g \sum_{i \in g} s_{i,g} \log(n_g s_{i,g}) \quad (3.2)$$

Where s_g is the participation of the salary in the total salary of the group or the g city; n_g is the number of observations of g city and $s_{i,g}$ is the participation of the individual i 's salary in g city. The first term of the equation (3.2) corresponds to interregional inequalities and the second one to intraregional inequalities.

The decomposition of inequalities by means of the Theil's index permits the calculation of which part of total inequalities is explained by the inequalities between the cities analyzed. This way it is possible to evaluate the importance of the regional component of inequalities.

Because distribution of the components is unknown, in order to evaluate the statistical significance of each component, the distribution of the interregional component is simulated to evaluate the significance of the localization effect of the income concentration patterns. The procedure consists in generating a random distribution of individuals among the cities considered using the bootstrapping or resampling method to obtain the distribution percentages and determine if the calculated amount is statistically significant.

Due to the fact that we are generating a distribution of randomly allocated individuals in space, they are also relocated in the simulations together with the expansion factors, and therefore we can distort the calculation of the size of the population in each city, which would add an additional source of variability in the results. To avoid this inconvenience, we use the expanded sample in such a way that the number of individuals located in each city is not altered, but only their spatial location. In this case the result would yield what would be the income concentration if individuals were shifted randomly between cities.

The interregional component of Theil's index is calculated in every wave of the survey and it is compared with the values for the random spatial distribution of the individual. The idea of this procedure is to compare the real interregional component, with what would occur if the individuals were distributed evenly in space. This procedure is repeated 99 times and 2.5 and 97.5 percentiles are generated which serve as a point of reference to determine if Theil's real interregional component is statistically different from the one obtained by "chance" or at random.

In the above analysis, we suppose that labor is an "homogeneous asset" that may be the object of interchange among regions with no barriers for labor mobility. Relaxing this assumption to analyze labor according to the educational level, it is found that there are results that differ in the wage convergence of the principal metropolitan areas, according to the labor segment analyzed (Galvis, 2004). It is not very plausible to make this supposition, and therefore, we have to study additional factors to understand the wage differences, for example, related with the theory of human capital, which includes education, experience, among others. Other variables such as gender and marital status are also included.

3.2.3. Conditional Sigma Convergence Using Micro-Data

The second focus consists in evaluating the difference wage averages in every city, conditioned to the control for wage determinants suggested by the theory of human capital in a Mincer type model (Becker, 1975).

Mincer (1962) focused his work on the measurement of the magnitude and rates of return on the job training, and most importantly, its implications in the distribution of

earnings. Mincer (1962) employed the net present value formula to estimate the rate of return on the average annual income in relation to the training costs, as follows:

$$\frac{d}{c} = (1 + r)n \quad (3.3)$$

In this case, d is the increase in job earnings after training has finished and c is the amount invested (measured as annual forgone earnings during the training period); r is rate of return of the investment; and n the duration of the training period. However, given that benefits and costs are not constant, and that life span is not infinite this formulation was not really employed for empirical analysis.

Becker and Chiswick (1966) stated that the income of a person i in period j , E_{ij} , were the result of the summation of the income had the investment not existed, E_{i0} and the summation of the annual returns of past investments, $\sum_{j=1}^n r_{ij} C_{ij}$. In this formulation r_{ij} represents the rate of return for a given individual, in a given period, given the amount invested, C_{ij} :

$$E_{ij} = E_{i0} + \sum_{j=1}^n r_{ij} C_{ij} = E_{i0} + \sum_{j=1}^n r_{ij} k_{ij} E_{i,j-1} \quad (3.4)$$

Taking logarithms and reorganizing previous equation it is possible to simplify it to:

$$\ln E_{ij} \cong \ln E_{i0} + \sum_{j=1}^n r_{ij} k_{ij} \quad (3.5)$$

Becker y Chiswick (1966) suggest that the product rk is the “adjusted rate of return”, and it is represented by r' . Now, if it is taken into account that the investment is constant, the equation (3.4) is simplified to:

$$\ln E_{i,j} = \ln E_0 + r'_i n_i + U_i \quad (3.6)$$

Where U_i is the error term and measures the impact, between individuals, of the rest of the variables that affect earnings. In this paper, the authors separated formal human education from other forms of human capital, to learn more about the effect of training over earnings. To this end, it was necessary to assume that r'_{ij} is the same for all levels of education, S_{ij} , differentiate r'_{ij} between levels of education, and consider explicitly the effect of work experience in earnings, yielding a new earnings equation such as:

$$\text{Ln}E_{ij} = \text{Ln}E_{i0} + r'_i S_{ij} + u'_i \quad (3.7)$$

This equation was termed the “education-earnings function”, and according to the empirical evidence, this formulation suggests a negative relation between years of education and the years invested in other forms of human capital. Moreover, their empirical results revealed rates of return lower than those obtained using Mincer’s (1962) equation.

Mincer (1974) states that considering a measurement of investments performed after school in the earnings function allows the researcher to know a great detail of the income distribution. This type of formulation was called the “human capital-earnings function”.

Mincer (1974) in turn reformulates the “human capital-earnings function” introducing nonlinear effects to experience, T :

$$\text{Ln}E_i = b_0 + b_1 S_i + b_2 T_i + b_3 T_i^2 + U_i \quad (3.8)$$

In the latter expression it is expected that the returns to schooling, represented by the parameter b_1 , be positive; the parameter b_2 , be positive and the parameter b_3 , negative. This means that experience has positive returns but at a decreasing rate.

From the latter formulation a series of variables that explain earnings have also been included. Among these it is possible to name gender, race, union status, and so on. Moreover, economists have raised criticisms to the earnings equation as it is argued that the returns to education are biased because the equation does not include the abilities of the individuals. Another element that has had great importance is the one added to the discussion by Heckman (1979, 1980) that is related to sample selection bias. This is related to the fact that the original analysis made from the earnings equation, considered only individuals who were working in the labor market. However, if more individuals with more human capital are self-selected into the labor market, the results of the analyses they are biased.

The correction for sample selection starts by formulating the equation to estimate from model of hedonic prices where the salary of the i^{th} individual in j^{th} city is modeled as:

$$\ln W_{ij} = \gamma_j D_j + X_{ij} \beta_j + \varepsilon_{ij} \quad (3.9)$$

In equation 3.9 the elements in D_j are regional dummies that identify the fixed effects in each city analyzed in the survey. It is well known in the literature of labor economics that when estimating the results with the above equation, they are biased when one does not consider the fact that the dependent variable has a truncated distribution, given that the salaries are not observed for people who are not working (Heckman, 1979).

In this case, the solution proposed by Heckman (1979, 1980) is to control for the probability of participation in the job market, for which equation 3.8 would be reformulated as the system:

$$\ln W_{ij} = \gamma_j D_j + X_{ij} \beta_j + \varepsilon_{ij}, \quad (3.10)$$

$$P_{ij}^* = Z_{ij} \theta_j + \mu_{ij}$$

In this system of equations P_{ij}^* is a latent variable that represents the participation probability in the labor market of each individual, or that of observing positive wages (Heckman, 1979). The error terms follow a multivariate normal distribution with mean zero, σ_μ y σ_ε , variances and ρ as the correlation coefficient which, together with the other parameters of the system, they are estimated by maximum likelihood.

Since the participation probability is modeled as a function of variables which affect salaries and the participation in the labor market, exclusion restrictions are included. These are used to identify parameters in equation (3.10).

An estimation alternative consists in predicting the probability of observing positive wages, and calculate with this the inverse Mills ratio, λ , as $\hat{\lambda} = \phi(Z\hat{\theta})/\Phi(Z\hat{\theta})$, where the numerator and the denominator correspond to the standard normal and the cumulative normal distribution, respectively. Mills inverse is included in equation (3.9) to generate a new estimation, which is known as Heckman's two-stage estimation:

$$\ln W_{ij} = \gamma_j D_j + X_{ij} \beta_j + \pi_j \hat{\lambda}_{ij} + \varepsilon_{ij} \quad (3.11)$$

It is recommended that the estimation be done by maximum likelihood if there are no multicollinearity problems in the model, in which case the estimation of two stages generates more robust results than the estimated by maximum likelihood (Puhani, 2000).

In wage models such as the one appearing in equation (3.10), the number of children less than six years old and marital status is usually used as variable added to the Z vector as exclusion restrictions. This same procedure is used in international studies (Dolton and Makepeace, 1986; Montero and Garcés, 2009). Heckman (1980) use the number of children less than 6 years home old and the hourly wages of the husband, in a study of the earnings equation of a sample of women.

The number of children and marital status are included in the present document, since we suppose that the presence of minor age children and marital status will affect the participation probability in the work force, but not necessarily the wage level that an individual receives. Dolton and Makepeace (1986) show that these variables affect the income through the term $\hat{\lambda}$, included in the wage equation.

In this part of the analysis, if significant deviations are found after controlling the set of factors considered in matrix X , which is supposed to determine the wage differentials, it may be concluded that there are significant differences in wages at the regional level. The existence of convergence in salaries will depend on their differential reductions through time (convergence), if they are maintained (integration of markets with no convergence) or if they are enlarged (divergence).

3.3. Previous Work

Differences in wages can be a product of inequalities in the interior of a country and it is expected that these inequalities disappear more quickly than between countries. The reason is that because the mobility of labor can help reduce wage inequality throughout the regions, because people would move to places where higher wages may be obtained until the relative supply of labor aligns with the demand and wages are more balanced throughout the different regions. This in turn would take the country's income to higher levels of growth. The above is based in the equity objectives and growth that can be positively complemented in such a way that the greater equity can lead to greater growth as argued by Lustig *et al.* (2002). Moreover, this last statement is in line with research that has found a negative relation between inequalities and growth (Deininger and Squire, 1996; Alesina and Rodrick, 1994; Bertola, 1993; Engermann and Sokoloff, 2002).

Previous studies in Colombia have analyzed the economic growth and convergence, suggesting evidence both in favor and against the convergence hypothesis (see Moncayo, 2002, for a review). These research lines began with the pioneer study of Cárdenas *et al.* (1993), which found evidence in favor of the convergence hypothesis over the 1950-1989 period. On the contrary, later studies unanimously rejected the idea that income is converging towards one equilibrium balance. Each one used different sets of data or estimation methods rejecting the convergence hypothesis (Rocha and Vivas, 1998; Bonet and Meisel, 1999; Galvis and Meisel, 2001; Bonet and Meisel, 2006).

In the Colombian context, and making reference to the theories of labor mobility and migration, Galvis (2002) presented an empiric application through a gravitational

model of spatial interaction. There he pointed out the importance and the magnitude of interregional labor mobility in Colombia. It was shown that, for the 1988-1993 period, the net interregional rate of migration in Colombia has a magnitude comparable to those of countries such as Spain, Ireland, Japan, and the United States. A fundamental conclusion of this study is the significant influence of the economic conditions in the regions of origin and destination of migratory flows with a special emphasis on income differences, as it has been documented in previous studies where it is suggested that the mobility of labor takes place according to a set of factors, where the difference of wages plays an preponderant role (Gallup, 1997).⁹

This high mobility of labor does not appear to have contributed to the integration of the labor market or the reduction of disparities in regional income, not even among urban areas, which are the ones that attract the greatest volumes of migration flows. This is evident when analyzing the income convergence in the principal urban areas of the country (Galvis and Meisel, 2001).

Bonet and Meisel (2006) furnished additional evidence in the same sense, using a series of per capita income built by CEGA (Center for Livestock and Agricultural Studies), based in the GDP after tax deduction and transferences to local governments, going beyond the studies that only use the per capita GDP.

Real wages have been used in the studies of the Colombian labor market integration. Such is a case of Nupia (1997) who studied the regional integration of the labor market of the four principal metropolitan areas. Later, Jaramillo *et al.* (2001) used

⁹ Martínez (2006: 323), even though reporting a high rate of migration in Colombia in relation with other countries, suggests that interdepartmental migration seems to respond very little to economic stimuli and that it responds more to the difference in life conditions such as safety.

the urban and rural wages of unskilled workers to analyze the integration of the labor market during the period 1945-1998. Both documents present advances in the discussion of average wages in the metropolitan areas or regions of the country. Nevertheless, it can be argued that the methodology used has ignored the analysis of the important characteristics of labor and regional markets that might affect the inequality in wages, such as the skilled workers and attributes of the labor and economic sectors where employees work. One of these characteristics is the level of education which was studied by Galvis (2004) for the 1984-2000 period. His analysis of the seven principal metropolitan areas to study the integration of the labor market, included qualified and non qualified workers and differentiated them by their level of education. The findings revealed that highly qualified or educated workers are more mobile than non qualified workers and that an analysis of the integration in the labor market should include both types of workers to be able to draw conclusions on the dynamic of wages in Colombia. The study concludes that there is integration for the highly qualified workers among some pairs of cities, but the same conclusion cannot be sustained for non-qualified workers.

Other types of work that move away from the perspective of the time series are those based on more micro-econometric foundations such as Mesa *et al.* (2008) and Ortiz *et al.* (2009), who study the labor market of the seven principal metropolitan areas during the period of 2001-2005. In Mesa's *et al.* work (2008), the distribution of wages is analyzed discriminating them by city and economic sector. The work uses non parametric proofs to compare distributions and verify if differences do exist. Moreover, Mincer type equations have been estimated to figure out the fixed effects per city and sector and

compare the differences that are not attributed to the productivity of individuals. These significant set effects constitute evidence of the labor market segmentation.

Ortiz *et al.* (2009), on their part, study the labor market segmentation during the 2001-2006 period, analyzing the formal and informal sectors to see if the differences in wages of both sectors still persist. They analyzed the different versions of a Mincer equation slowly including variables of the size of the companies, regional dummies for thirteen metropolitan areas, interactions of the dummies with education, and spline variables of education. In all the cases, the dummy variables that identify small or informal companies show negative and significant coefficients, which imply that there are remunerations that are consistently under those paid by large and formal companies, or that, in other words, there is segmentation in the labor market.

This paper is different from previous research in several aspects. In the first place, the analysis uses real wages to study the convergence hypothesis, rather than the GDP and other variables that have been used in former studies. In the second place, to control for the difference of attributes of labor, we use conditional average wages. In the third place, we consider the sample selection bias—for non observed wages—because not including them leads to biased calculations that result in minor differences of the average conditional wage. Therefore, it is centered in the relation between wages in the regions using the National Household Survey, NHS, the Continuous Household Survey, CHS, and the Great Household Integrated Survey, GHIS, which take place in the principal cities and metropolitan areas in the country. Even though this focus limits the reach of our conclusions for the urban market instead of doing it in the national labor market, it

has the advantage that it considers the selection bias and analyzes both qualified and non qualified workers.

The purpose of this analysis is to evaluate the convergence hypothesis in real wages and obtain conclusions from a perspective of time series and cross-sectional data. To do so in a precise way, it is argued that to evaluate the convergence hypotheses, the analysis of the simple average wage is not enough in itself, because variation between different labor markets may arise. These variations may have origin in the attributes of sectors that, in each metropolitan area is specialized in work attributes or those of the worker. We also consider the characteristics of labor which are not homogeneous in all the labor market (Galvis, 2004; Mesa *et al.*, 2008). Furthermore, we analyze a larger and more recent period and we consider the differences in economic activity in regions as to key matters such as the economic sector in which the employees are working because, given the industrial composition of each region, there may be differences associated with specialization.

3.4. Data

The National Home Survey (NHS) is used in the first part of the work for the period 1984-2000 with a quarterly frequency. Later, the data is linked with those of the Continuous Household Survey (HCS) from 2001 to 2006 and the Great Household Integrated Survey (GHIS) from 2006 to 2009. Since the methodology of the household surveys changes between the types of surveys to make the analysis more consistent, a fraction of the work force was used representing the employees of the private sector who work at least 40 hours per week. This allows us to analyze a more homogeneous group of

workers for which there should be less inflexibility in the salaries and we would expect more fluctuations in them, which might eventually lead to a convergence of salaries.

Some groups of workers that are excluded from the sample are, for example, the self-employed, for which there is no salary per se, but an income, which is associated with the fluctuations of the work in the informal market. To this respect, Guataquí *et al.* (2009) report differentiated results for employees and the self-employed workers, justifying the treatment of both groups in a separate way in the wage models. Another group that was excluded from the analysis is the public employees, whose salaries are adjusted according to institutional factors that may impose inflexibility that may complicate the analysis of convergence. A similar work strategy is found in Bratsberg and Turunen (1996) and in Arango *et al.* (2010).

To make the analysis more manageable, we only took data for the second quarter in each year.

To consolidate a series with a large coverage in the temporal dimension, we only included the seven principal metropolitan areas in the analysis when the NHS was used. Beginning 2001, a separate analysis was made for the seven and thirteen cities available.¹⁰

Real wages were calculated with nominal salaries, deflated by the consumer price index base 2008. Since it is possible that there are some differences in the cost of living in cities that affect the wage compensation (Roback 1982, 1988), price indexes were used

¹⁰ The cities were Barranquilla, Bogotá, Bucaramanga, Manizales, Medellín, Cali, Pasto, Cartagena, Montería, Villavicencio, Cúcuta, Pereira, and Ibagué.

for each metropolitan area.¹¹ To capture the importance of the industrial composition on salary differences, fixed effects have been included for each one of the economic sectors, since we expect that a part of these salary differences is explained by the economic sector where the employees are working.

3.5. Results

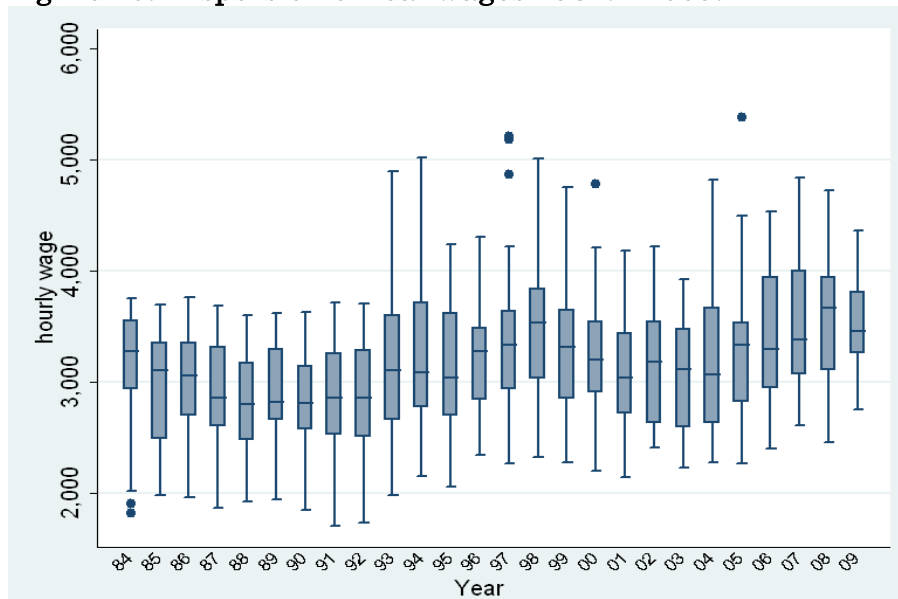
The first focus used to characterize the behavior of urban wages is based on analyzing trends through time and exploring the patterns suggested by the dispersion of data. The main question to be solved is if there exists unconditioned sigma convergence, examining the wage variation coefficient. The second part of this section seeks, by controlling the difference inside the cities, to verify the contribution of wage dispersion that the studied cities have in the frame of conditional sigma convergence. Finally, we use the analysis of micro data for the study of the conditional sigma convergence, controlling the factors that influence over wage differentials in hedonic models.

Figure 10 shows the behavior of wage dispersion in the metropolitan areas of the study using variation coefficients. The graph makes evident that in general, the series for the majority of the cities shows a decreasing trend in its dispersion towards the end of the nineties. Nevertheless, during the following years dispersion enlarges again and with it, the wage gaps increase once again. Nevertheless, note that if one observes the mean behavior (the line drawn inside the bar), it does not vary significantly, compared with the distribution extremes, thus other distribution percentiles would be the ones explaining the variations in salary dispersion.

¹¹ Except during the period 1984-1987, for which price indexes at a national level were used for each one of the cities.

Finally, to the question of the reduction in wage differentials, according to Figure 10, we have to respond negatively. The variability of wages among metropolitan areas shows cycles where there are increases in dispersions and in others, reductions. Nevertheless, if one examines all the series for the analysis period, a general reduction is not observed in the disparities of regional average wages. In other words, the non-conditional sigma convergence is not observed; that is, there is not “strong” convergence.

Figure 10. Dispersion of real wages 1984.1-2009.2



Source: The author's calculations based on DANE.

3.5.1. Interregional Disparities in Wages

When comparing the variation coefficients through the different periods of study, we find great variability in these (Figure 10). The first analysis calculates the wage differentials, explained by the location of individuals in some of the cities considered. That is, because there are wage disparities at the regional level, what one wants is to

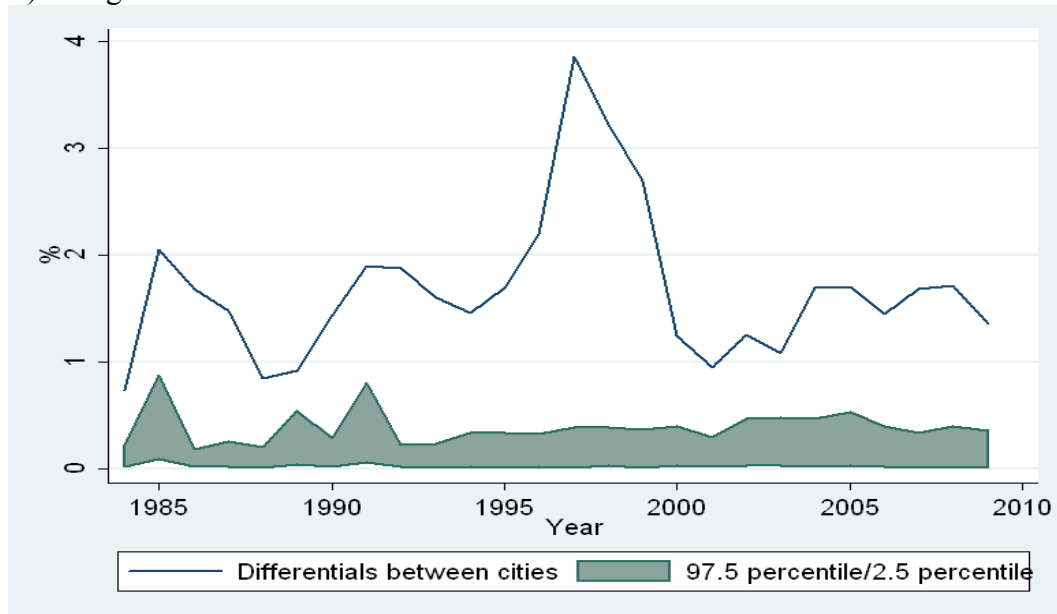
investigate is the contribution of the regional component of Theil's index to total inequalities in the frame of conditional sigma convergence.

Conditional sigma convergence would not be refuted if, according to this methodology, there had been reductions in the interregional component of wage disparities. Figure 11 shows the participation calculations of interregional inequalities in the total inequality. The area between 2.5 and 97.5 percentile of the calculated indexes from the relocation of observations is also calculated. It is represented by the shadow strip.

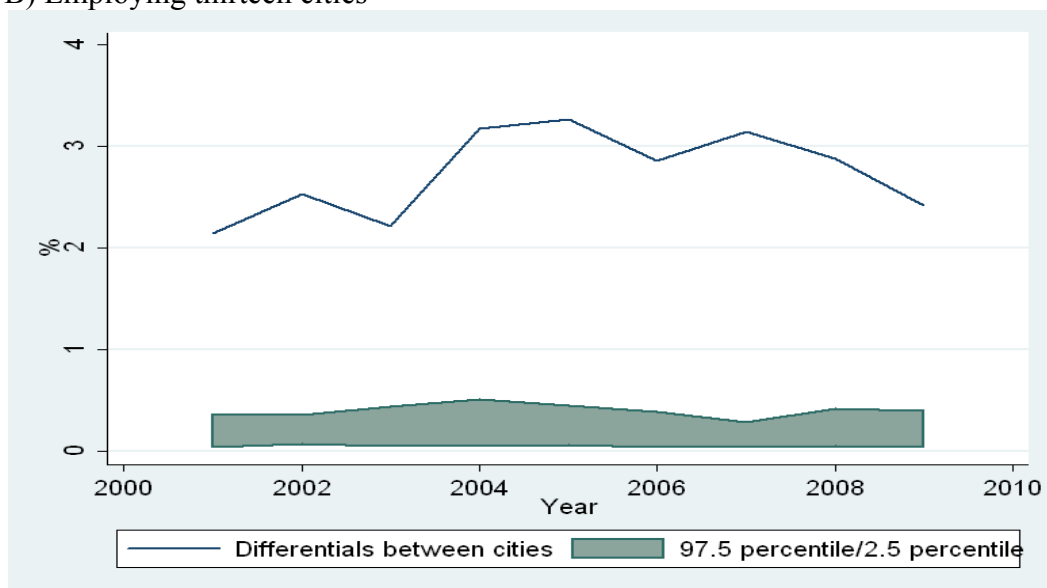
It cannot be said that there was a generalized increase in interregional disparities, nor can it be concluded that these were reduced during all the analyzed period. Moreover, one can identify two differentiated periods. The first one until 1997, where a trend in the increase of regional wage disparities can be observed, followed by an abrupt drop in these differentials. The second one starting the year 2000 where one can observe once again an increased tendency in the observed differentials. Nevertheless, note that in the second period the average of those differentials is much less than the levels reached at the end of the first period.

Figure 11. Contribution of city cities to wage differentials, 1984:2-2009:2.

A) Using seven cities



B) Employing thirteen cities



Source: The author's calculations based on DANE.

An element that deserves attention is the percentage, from the total disparities, that represents the regional component. It would certainly seem that this percentage does not have greater relevance. Nevertheless, when comparing the figures with the values that would have been obtained if the population would be distributed randomly in the space

(localized between percentiles 2.5 and 97.5), one can find that the calculated values are significantly different from those hypothetical figures. This means that, controlling for disparities within the cities, the differences among cities contributes a significant percentage of the total wage disparities among cities. In other words, space does matter in the explanation of wage differentials.

3.5.2. Estimation of Wages Equations

In this section, additional control variables are used to explore the regional differences of real wages in the main metropolitan cities in Colombia. Wage equations are estimated for several stages of household surveys to cover not only recent tendencies in the labor market, but also the former behaviors that are important for our analysis.

In Mincer type wage models, variables used regularly to study the factors determining wages were included, such as the level of education, age, marital status and characteristics of the gender and work, according to the theory of human capital (Becker, 1975). Additional control variables included in this analysis show results coherent with the results traditionally obtained for this type of estimations, particularly those in respect to the coefficient signs of wage determinants. For example, results point to wage earnings lower for women in general, while age, as a proxy of experience, shows a positive effect over wages, but with increases at decreasing rates.

The principal object of this analysis is the identification of city effects, which identify individuals living in Barranquilla, Bucaramanga, Cali, Manizales, Medellín and Pasto, in the case of the seven cities. When analyzing thirteen cities, we additionally

included Cartagena, Monteria, Villavicencio, Cúcuta, Pereira and Ibagué. In both cases the base group of comparison is Bogotá.

According to the results, with rare exceptions, all the fixed effects are statistically significant in all considered surveys.¹² This would show that there are significant differential impacts, due to the location of the individual, explaining the wage disparities in the analyzed cities. These disparities are evaluated in relation to Bogotá, which, as it was stated before, is taken as a reference group.

In this part of the methodology, regressions were obtained with Heckman's methodology using maximum likelihood estimation. The second quarter of each year from 1984 to 2009 was used for seven metropolitan areas, and for the period of 2001–2009 for the thirteen principal metropolitan areas. The effects of each city are analyzed, representing the differentials of the conditional wage media, after controlling other factors which affect wages.¹³

Taking the second semester of the year 2009 as an example, Table 4 shows that conditioning on the other factors that affect wages, in Barranquilla, on average, it is observed that wages are 21.2% under those in Bogotá.¹⁴ On the other hand, the city of Pasto will have a wage average which is 32.4% under the one observed in the capital. Notice that the main cities, such as Cali, Medellín and even Bucaramanga, present wages very near in average, since their differences vary between 5 and 8% below those of

¹² For simplicity only the fixed effects with their respective standard error were included (see ANNEX C). Calculations report the robust standard errors in order to be consistent with the presence of heteroskedasticity in this type of estimations.

¹³ Because the results represent a vast extension of information, all the estimated models are not included in the tables, but the summary of the coefficients of interest.

¹⁴ The percentage differential calculus of wages among metropolitan areas takes place with the equation, $\Delta W_{rt} = (e^{\beta_{rt}} - 1) * 100$, where β_{rt} is the coefficient of the fixed effects for each metropolitan area or region r , and t indicates the period of time.

Bogotá. This amount represents one fourth of the differential of Pasto, and less than half of the differential in respect to Barranquilla, Manizales, Cartagena, Montería and Ibagué.

Table 4. Fixed effects by cities in the wage model in 2009:2.

Dependent Variable: Log(hourly wage)	Coefficient	Standard Error	p-value	95% Confidence interval	
Fixed effects:				Lower limit	Upper limit
Barranquilla	-0.2392	0.0202	0.000	-0.2787	-0.1996
Bucaramanga	-0.0714	0.0211	0.001	-0.1128	-0.0301
Manizales	-0.2271	0.0322	0.000	-0.2902	-0.1640
Medellín	-0.0527	0.0117	0.000	-0.0756	-0.0297
Cali	-0.0868	0.0150	0.000	-0.1162	-0.0574
Pasto	-0.3924	0.0426	0.000	-0.4759	-0.3089
Cartagena	-0.2243	0.0285	0.000	-0.2801	-0.1685
Montería	-0.2538	0.0436	0.000	-0.3393	-0.1683
Villavicencio	-0.1333	0.0356	0.000	-0.2031	-0.0635
Cúcuta	-0.1343	0.0259	0.000	-0.1851	-0.0835
Pereira	-0.1164	0.0266	0.000	-0.1684	-0.0643
Ibagué	-0.2287	0.0306	0.000	-0.2886	-0.1688

Note: The table continues with the rest of the variables of the Mincer type model and the corrections of sample selection bias, but to simplify only the coefficients used in the analysis of the convergence graphs are shown.

Source: Authors calculations based on DANE.

The question that we want to answer with the estimation of the fixed effects is if those wage differentials -conditioning on personal and industry attributes- increase, are reduced or maintain themselves through time. To accomplish this, a time series has been constructed with the estimation of the wage models, and its trend through times has been evaluated.

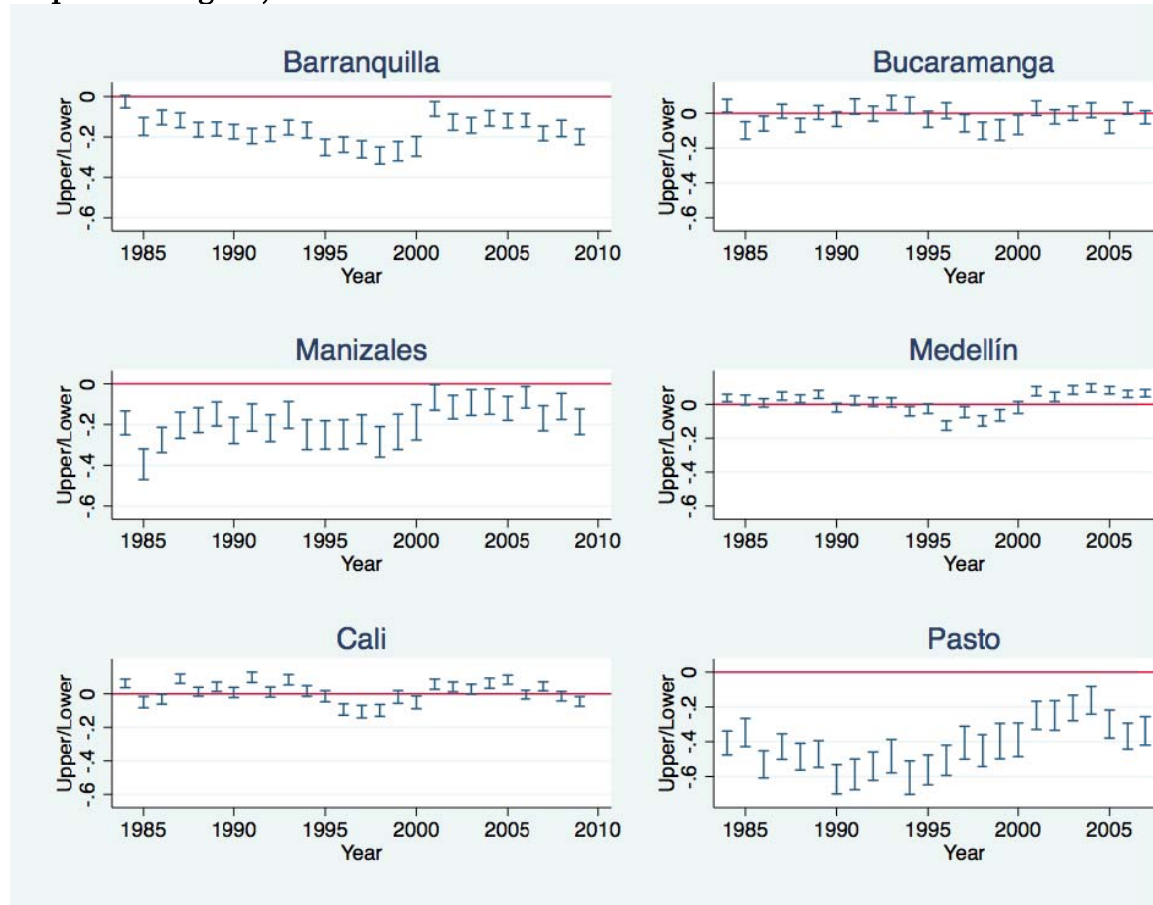
Figure 12 presents fixed effects for the seven principal metropolitan areas from 1984 to 2009 and Figure 13 shows the results including the thirteen principal cities from 2001 to 2009. In general, it is observed that these differentials through time do not show a

tendency to decline. Exceptional cases are Manizales and Pasto. The first city showed differentials in the 20% average order during the 1990s and towards the end of the period they were reduced to half. For its part, Pasto also reduced its differential to half, but the differences with the other metropolitan areas are still very large because in the 1990s, the differential of salaries in cities in respect to Bogotá was 50% on average and it shifted to a differential of 25% towards the 2000-2009 period.

The analysis repeatedly points Cali, Bucaramanga and Medellín as the nucleus of the economic activity (center) where wages are closer to those in Bogotá, the highest wages in the country in relation with the other metropolitan areas (periphery).

It must be stressed that, in general, the results of the analysis presented up to now clearly show the notion of a persistent pattern in the regional wage differences among metropolitan areas, because the dispersion of the unconditional measure of salaries is not reduced in time. With this result in mind, one cannot speak of strong convergence in Dickie and Gerking's (1988) sense.

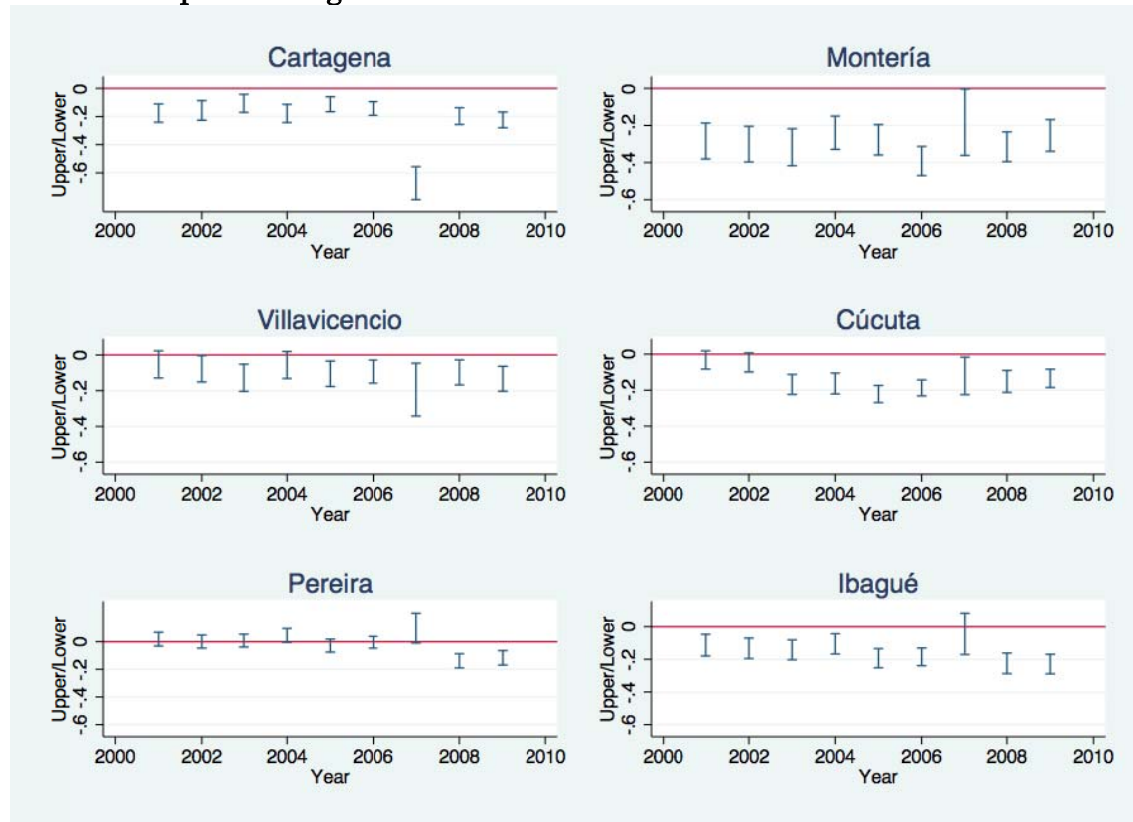
Figure 12. Comparison of fixed effects in the principal metropolitan areas in respect to Bogotá, 1984-2009.



Note: The graph shows the coefficient of the set effect in each city, and the confidence interval. The figures represent the percentage of the average wage differential in respect to Bogotá.

Source; Author's calculations based on DANE, NHS, HCS, GHIS

Figure 13. Comparison to the fixed effects in the main small metropolitan areas in respect to Bogotá. 2001-2009



Note: The graph shows the coefficient of the set effect in each city, and the confidence interval. The figures represent the percentage of the average wage differential in respect to Bogotá.

Source: Author's calculations based on DANE, NHS, CHS, GHIS

After controlling the determining of wages in an hedonic model, the remaining differences are interpreted as the existing inequalities among wage remuneration in the country's principal cities. These inequalities of the labor compensation in the center, compared to the country's periphery, play an important role in the non convergence of wages, which lead to the fact that there is no "weak convergence", or sigma convergence conditioned on the attributes considered in a Mincer-type model for wages.

For future work, it is important to consider specific information on cities to compare the differences in the salaries given the attributes of the cities and develop an analysis in an aggregate level to explore the possible explanation for the existence of wage differences and their persistence, something that has been already advanced in Arango's *et al.* work (2010) in relation to unemployment.

Finally, a note of caution in relation with the fact that, due to the lack of information in household surveys, variables such as race, union affiliation and experience, among others, are not included and which would probably be important to analyze the sources of wage differences.

3.6. Concluding Remarks

In the search for understanding the dynamics of wages among Colombian metropolitan areas, this study is differentiated from previous studies to analyze the convergence hypotheses among the principal cities of the country, by using the household survey data for the period 1984-2009. In contrast with previous studies on the topic, an alternate convergence of income is developed in this study which spins around two principal points: the use of a series that shows the behavior of real wages in several periods of time and the use of cross-sections for the microeconomic analysis of the determinants of wage differentials.

The results indicate that there is no evidence that supports the unconditional convergence hypothesis of wages in the principal cities of Colombia. Conditional sigma convergence was analyzed through the participation of the inequalities of salaries among the main cities, finding that those wage differences were not reduced though time, that is, that there is no evidence of conditional convergence.

On the other hand, the results of the cross sectional analysis show that, even those employing the series of real wages and controlling the attributes which regularly explain the wage differences, there are persistent differences in urban wages among the Colombian metropolitan areas. This finding is particularly critical for the case of Pasto, Cartagena, Montería, Villavicencio, Cúcuta and Ibagué, cities found in the country's economic periphery.

As a result of this analysis, it can be suggested to revise the current policies to reduce income inequalities among regions, allowing a convergence process in the distribution of income. This is fundamental if one considers that in several studies have documented that greater inequalities can lead to lesser economic growth.

It is important to identify the specific attributes for future works to determine the wage difference in them. For example, it would be interesting to control for the cost of living, the amenities of the cities and their influence over the wages, and also the industry mix in every metropolitan area. At the same time, it must be recognized that, due to the structure and design of the data of household surveys, it was not possible to include in the model control other variables that can be important in the analysis of the wage differences, such as race, union affiliation and experience, because these variables are not available in the surveys.

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CHAPTER 4

INNOVATION AND GEOGRAPHY: AN EXPLORATORY ANALYSIS OF PATENTS IN THE US

Abstract

In this paper I am assessing the extent to which innovation is affected by the structure of the economy in terms of the industrial specialization, diversity and competition. Innovation is proxied by the number of patents registered in the US at the county level. The paper assesses the extent to which there are spatially varying coefficients which is a form of spatial heterogeneity, that has not been considered previously either. Exploratory spatial data analysis provides evidence to support the claim that the spatial heterogeneity is present and thus, it warrants a formal treatment of this phenomenon. The exploratory data analysis of the innovation rates for the year 2000 reveals that there may be some spatial heterogeneity present in the model and that suggested the use of a Geographically Weighted Regression approach to evaluate the spatial non-stationarity of the relation of the economic structure to the innovation intensity.

4.1. Introduction

Local development based on knowledge seems to be the key factor for the success of places like Silicon Valley and Route 128: instead of the classic view of exogenous technological change, these places are arguably following the path demarked by

endogenous growth theory (Romer, 1986) in which economic development mainly depends on technological change, and the latter is determined by internally planned investments on research and development, R&D, that in turn yields some innovations that booster economic growth. Further, models of endogenous growth introduce imperfect competition by allowing innovators to have certain monopoly power or considering that the possibility of having monopoly power over the innovations is what drives the motivation to invest in R&D (Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992; Young, 1928).

I am interested in testing the relation of the innovations, measured by the number of patents registered, to the structure of the economy in terms of the specialization, diversity and the degree of competition, which constitute factors that has been identified to matter for economic growth, especially in the urban environments (Glaeser *et al.*, 1992). The paper analyzes whether there is heterogeneity between the relation of innovation and economic structure assessing the extent to which geographically varying coefficients are present in the phenomenon studied. The anticipated result, if we are referred to the distinction made by Saxenian (1994) regarding Silicon Valley and Route 128, is that the effects of some of the independent variables may change depending on the region analyzed as the structure varies throughout, in terms for instance of the degree of competition or cooperation between firms. The last step is to consider this heterogeneity and estimate a model with spatial effects that addresses this heterogeneity.

Different theories of the relationship between innovation and regional economic structure have motivated this work, that examines how characteristics of a regional economy at the county level in the US affect production of new knowledge or innovation.

Marshall's (1920) theory of specialization, Jacobs' (1969) theory of diversity, and Porter's (1990) theory of competition will constitute the grounds to examine empirically the determinants of innovation. In this paper I examine if those three theories are supported by the data in the US. The first approach tests for empirical relations facing the singularity presented for this phenomenon, in the sense that there is a relatively high proportion of counties with no innovations. This may create a problem because the number of zeros in the sample biases the distribution and then the parameter estimation is not reliable.

It is expected that diversity and competition will foster innovations. It is also feasible that specialization and diversity are not homogeneous through space, which suggests that their effect on innovation is not homogeneous either. In this sense, it is expected that different effects are found when performing local analyses of the phenomenon of innovation.

The main contribution of the paper is that, first, it undertakes an approach to test for empirical relations considering the dichotomy presented among the US counties for which there is a high proportion of counties where no innovations are registered. When that issue is not tackled in it may yield problems in the sense that the number of zeros in the sample biases the distribution and then the parameter estimation is not reliable. Using only the counties with positive counts of patents will hide an important part of the innovation process, such as the importance of the factors that permit the birth of new patentable ideas.

The second section introduces the theoretical formulation of the problem. Third section describes the data set employed. Sections four and five develop the modeling

strategy to analyze the innovation activity. Section six addresses how those space-varying coefficients help us understand the distribution of innovations and their relation to economic structure. Lastly, section seven concludes.

4.2. Innovation and Economic Structure

There have been many studies of the relationship between innovation activity and regional economic structure. The most interesting are theories presenting competing perspectives of the same phenomenon. We have mentioned Glaeser *et al.* (1992) who argued that technological specialization facilitates knowledge spillovers between firms of the same industry. This claim was supported by experience of the electronics and microchips in Silicon Valley where the localization of skilled workers and the availability of intermediate inputs would allow individual firms to have reductions in costs. Firms in this area were encouraged to produce new knowledge by mutual spying, movement of labor, and idea flows, it is argued (Glaeser *et al.*, 1992). By contrast, Jacobs (1969) argued that variety and diversity of geographically proximate industries favor spillovers of innovation. In her case the example of the brassiere industry, for instance, innovated because of influence of dressmakers' industry. In similar way, there have also been alternative theories about the effects of monopolistic industry structure on innovation activity. Based on the example of the Italian ceramics and jewelry industry, Porter (1990) argued that competition is more conducive to knowledge externalities than is local monopoly, while from a Schumpeterian perspective it is stated that price reductions caused by adoption of new knowledge forced firms not to invest in innovation activity

because it makes it more difficult to recoup the initial investments, in which case a monopoly be more motivated to innovate (Schumpeter, 1942).

Innovation is considered a knowledge intensive activity (Black and Lynch, 1996). Investments in human capital are related to the purpose of fostering knowledge and those investments at the firm level are manifested through on-the-job training and education with the ultimate purpose of increasing productivity and competitiveness of the firm.

Along the same lines, it has been widely recognized that human capital plays a very important role in introducing or producing new knowledge. According to Bordieu (1986), employees who are better educated have more work experience and skills, and tend to contribute more to introduction, adoption and distribution of new knowledge. These types of employees constitute a fraction of the specialized labor hand and are thus better paid.

It is important to recognize a link that is missing so far and that is the fact that skilled human capital is required to complement the investments in research and development (R&D). By the same token, in order for investments on R&D to be translated in more productivity, it requires skilled and knowledgeable human capital.

Pakes and Griliches (1980) used patents in relation to expenditures in R&D of some large and medium size corporations in the US. The objective was to explain the variance in the number of patents applied during 1968-1975 and the R&D expenditures from 1963-1975. To the extent that R&D expenditures are directly related to innovations, it was plausible to pose that innovations are related to patents. The conclusion from this study is that there is a strong relation between R&D and the number of patents in a cross-sectional framework, even though over time the relation was not as strong.

Jaffe (1989) uses patents to proxy “new innovations” and their relation to university research. The author employs statistics at the state level and finds a significant effect of university research on corporate patents. After this work the quest for “technology transfers” has been termed the Griliches-Jaffe “knowledge production function” as it uses a Cobb-Douglas type of production function in which the production of innovations is related to two inputs coming from R&D activity: industry and university R&D. This is part of the literature dealing with “technology transfers” that is according to Parker and Zilberman (1993) conceptualized as the mechanisms by which information and innovations are “transferred” to private organizations.

Feldman (1994) and Feldman and Florida (1994) extended the knowledge production function framework by adding the distribution of manufacturing, and distribution of producer services. Using the data for counts of innovations in 1982, they show that geography does matter for innovation. Feldman (1994) and Feldman and Florida (1994) as well as Acs *et al.* (1994), Anselin *et al.* (1997) use a different measure for innovation that was compiled by the U.S. Small Business Administration. The database is actual counts of innovations that were produced for that year.

Using the knowledge production framework with the dataset of innovations for 1982 and including spatial effects on their models, Anselin *et al.* (1997) observe significant spillovers originating from university research to innovative activity in high-tech sectors, working with the 125 largest MSAs. As with previous research using innovation counts, Anselin *et al.* (1997) limited their analysis to study just the areas for which both research and innovations exist, and no treatment of the places where zero innovation counts are observed and research exist e.g. places like Champaign county and

the area of influence of the University of Illinois, as well as other research centers from universities located in small towns were not included in the analysis.

Unfortunately those data for counts of innovations were not longer compiled and that explains why most of the following literature relies on other proxies to measure innovations.

Saxenian (1994) posits that the success of Silicon Valley is in great part explained by the existence of intensive flows of specific knowledge among firms complemented with more open communication and interchange. Another successful case of innovations is the Route 128 but this example seems to have been evolved out of a culture of secrecy and limited interaction or cooperation among firms and those elements have induced a lag with respect to Silicon Valley where firm networks and cooperation seem to be a boost for industrial development and growth. Route 128 is more characterized by large firms that have their networks operating internally (Saxenian 1999). This observation has some implications in terms of how the spillovers and externalities may influence entrepreneurship and innovation, in Silicon Valley these elements seem be more dynamic.

O' hUallachain and Lee (2010) investigate a similar issue regarding specialization and innovation. Instead of using the Herfindahl-Hirschman index for specialization, the authors employ the Theil index, which is related to the innovation rate during years 1995-1999. The authors employ a sort of “discrete” space, as the units of observation are the metropolitan statistical areas. According to the results, it is specialization that is related to the patenting rates.

As noted previously, there is no complete consensus about the relationship between innovation and specialization or monopoly of industry in a region and the idea with this paper is to test those multiple theories to provide evidence to shed some light upon the discussion.

These different theories of the relationship between innovation and regional economic structure served as the incentive and motivation for this paper that is aimed to examine how characteristics of regional economy at the county level of the US affect production of new knowledge or innovation. Based on these theories, three hypotheses are tested: 1) the degree of specialization affects positively innovation, 2) counties with more degree of competition innovate more, and 3) counties where employees are more skilled, proxied by the percentage of college graduates and average wages, are more prone to innovation.

In this paper I examine if those three hypotheses could be justified or not by applying regression modeling at a first stage separating observations by that have zero innovations and the ones with non-zeros in a Hurdle Regression Model framework.

4.3. The Data

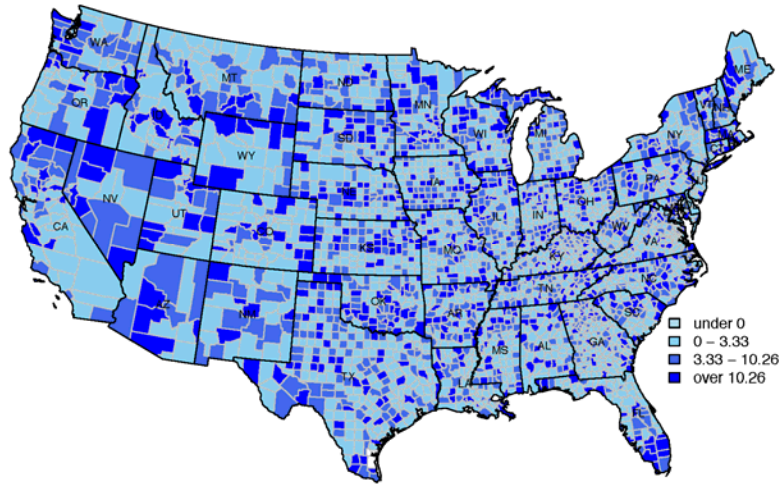
The data set consists of the dependent variable that corresponds to the counts of the innovations or patents registered in each county in 2000 from the US Patent and Trademark Office, USPTO. The dataset contains different records for the patents assigned, technological class, and so on. The assignees dataset contains personal data for the applicants, from which the address is used to geocode each patent record to match them to the assigned patents data set.

The database for the patents has been made available under a NBER project from 1963 to 1999 (Hall et al., 2002) and later updates followed up until 2002 and later on until 2006. However the latest data does not make publicly available the information for the assignees that provides very useful information, such as the geographic location of the patents¹⁵. Without it, we cannot assign patents to the counties. The 2002 version of the data has all the information required, however the latest years have just a few records, e.g. 2002 has 1,664 and 2001 has 38,868. These figures are not very significant compared to the year 2000 that has 107,042 records.

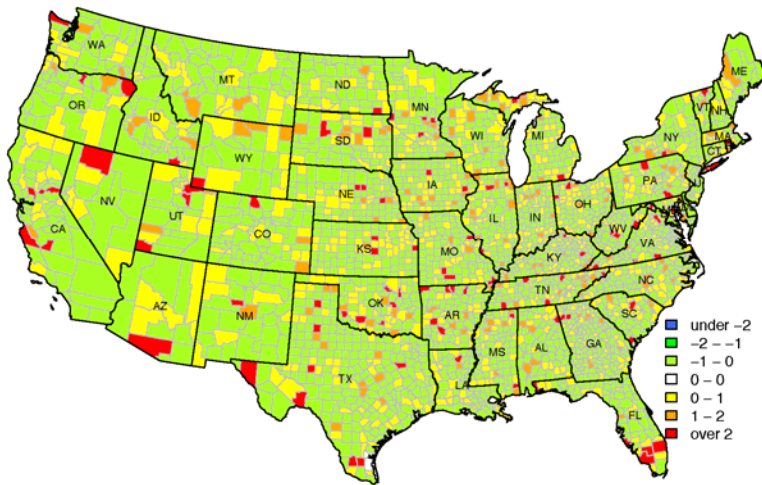
I selected the year 2000 as the sample data to analyze because it has the higher number of records available in the database and that helps in providing more variability in the innovation patterns, as well as more representativeness of the geography of the study area.

¹⁵ This may be the reason for which O' hUallachain and Lee (2010) worked with a sample data covering just until 1999.

Figure 14. Distribution of per capita patents in 2000.
Panel A. Quartile map



Panel B. Standard deviation map



Source: Author's elaboration.

It is fair to say that the number of patents is not distributed homogeneously through space. In fact, even though the sample year was selected to optimize the variability in the innovation patterns, there are a great proportion of counties where no patents have been registered as shown in Figure 14. In panel A, for instance it is clear that the presence of zeros in the sample is quite important, as the quartile map shows a large proportion of counties where the number of assigned patents is zero. If the data are drawn

to take into account the distribution of the values plotted, results point to a similar conclusion. This can be observed in Panel B where a standard deviation map of per capita patents is presented.

The explanatory variables used included the number of employees and firms, wages and size of the firms by economic sectors, obtained from a data set of the county Business Pattern from the US Census Bureau. The data for the number of patents by county was constructed by geocoding the addresses of inventors by place of residence, and then by a spatial match those locations were linked to the county polygons map to aggregate at that scale of analysis. When two or more inventors exist the address of the first listed inventor was used. This simplification may not yield representative origins for the innovations, but it is assumed that this route is less critical than double counting patents when considering two or more inventors.

These variables allowed us to construct the variables: Herfindahl-Hirschman Index (HHI), Competition Index (CI), and average wage, and the proportion of small firms in each county (small) to have an approximation of the effects of firm size to innovation, even though it is clear that with this analysis we cannot conclude whether the small firms are the ones who innovate or not as that type of argument will fall into the “ecological fallacy” problem.

HHI explains the degree of specialization or diversity of industry structure within a county, and is calculated as the sum participation of economic sector i in the employment of all the m sectors present in a given county j . As the economy is specialized (diversified) and the participation s_i is relatively heterogeneous (homogeneous) the HHI yields high (low) values:

$$HH_j = \sum_{i=1}^m s_i^2$$

Where the term s_j is defined as follows:

$$s_i = \frac{E_i}{\sum_{i=1}^n E_i}$$

On the other hand, I follow Glaeser *et al.* (1992) for the calculation of CI, who suggested a measure expressed as the number of establishments per employee in each county divided by the same ratio for the industry in the whole economy:

$$CI_j = \frac{[\# \text{ of firms in city } j / \# \text{ workers in city } j]}{[\# \text{ of firms in US industry} / \# \text{ workers in US industry}]}$$

A greater value than the unity means that the local economy is more competitive in comparison to the average (Glaeser *et al.*, 1992). Average wage is obtained from the ratio of the total payroll over the number of employees.

Because definition of what is urban and what rural is an important factor in terms of the question motivating this research, it is important to clarify the definition adopted in the paper for the urban areas. The common practice in this matter is that metropolitan areas are considered urban and conversely what is non metropolitan is considered to be rural. This definition brings the problem that the Grand Canyon is supposed to be in metropolitan America (Isserman, 2005). Also there are “urban” counties which mainly depend on farming. To avoid such problems originating from the urban/rural dichotomy the paper considers that a given county may be categorized as urban in terms of the population size but rural in terms of the economic dependence, so it is the degree of

urbanization what is taken into account in this paper. To this end the data from the counties typology built by the Economic Research Service of the US Department of Agriculture are used. However, instead of using their typology I construct a factor –using factor analysis- that includes the category of being a large metropolitan, a small metropolitan, micropolitan and a non-core county in the area of influence of a large metropolitan area. The factor also includes the dependence on manufacturing and services, population size, density as well as per capita income¹⁶. It is assumed that all those variables are positively correlated with the degree of urbanization in a given county. The result of factor analysis yielded one factor with an eigenvalue greater than one and then just this main factor was used in the analysis.

To validate the results of this part of the analysis correlations with other variables that may indicate a degree of urbanization were calculated. The results show that the urbanization degree is positively correlated with the number of jobs, number of workers and percentage of population completing college, and it is negatively correlated with the degree of poverty. Isserman (2005) shows in his categorization of urban/rural that the higher the income, the less rural and that poverty rate is higher in rural counties and it reduces as rural counties are integrated to urban areas, which is consistent with the results of presented in this study.

¹⁶ The data is available for 1989 and 2004.

4.4. Modeling Innovation and its Intensity

4.4.1. Patents as Measure of Innovations

Patents have been used to proxy for innovations for a long time now. Scherer (1965) Comanor and Scherer (1969) study patented innovations and their relations with economic output. Griliches has been more recognized in terms of the empirical contributions to these issues probably because he joined the discussion when the database of the US Patent and Trademark Office, USPTO was computerized and thus more easily to access (Griliches and Pakes, 1980). Other important contributors are Jaffe (1989) who used patents as measure of new innovations and tested for university effects on innovation.

Patents have been used to measure the “generality” of the innovations by evaluating the degree of concentration among the sectors of the Standard Industrial Classification, SIC. If the citations are widely dispersed across technological classes then the innovations are said to be more general (Trajtenberg *et al.*, 1997).

Originality of the innovations has also been captured by looking at patent citations. Trajtenberg *et al.* (1997) calculate a measure of concentration for the citations and propose that the larger is the index of originality the more basic the research and the innovations.

Nonetheless, when working with any proxy, there are certain limitations that researchers have to face when patents are used to approximate the level of innovation. The first one that is widely recognized is that not all innovations are patented. This result stems from different reasons. Hall *et al.* (2002) summarize these in different categories.

The USPTO defines certain criteria to consider an invention to be patentable and not all inventions satisfy those criteria. One important criterion is that the invention has to be marketable i.e. it has to be susceptible of yielding a product of commercial value. A second characteristic that is more difficult to meet, as it is more dependent upon the subjective judgment of the reviewer, is the requirement that the invention has to be “novel and non-trivial”. Finally, even though there may be innovations that meet the criteria set by the USPTO, inventors and firms sometimes prefer to keep their innovations as part of their “industrial secrets” and not patent the innovation.

On the other hand, some other caveats to consider may include the fact that a patent may not reflect the importance or value of the innovation. Innovations for some type of industries may have required more investments in R&D in comparison to other innovations. Along the same lines, patents by no means provide a measure of the importance or significance of the innovations.

In spite of these criticisms, patents have provided the best publicly available data to proxy for innovations.

4.4.2. Modeling Strategy

It is well known that for a random variable whose distribution is Poisson the variance is equal to the mean. The presence of more zeros than predicted by count models leads to invalid results when fitting, for instance, a Poisson model for the counts of innovations, due to the fact that the excess of zeros causes overdispersion (See, among others, Ridout *et al.* (1998), Yau *et al.* (2003) and the references therein for further details). On the other hand, the presence of zeros may be the result of having a zero

probability of observing a positive value in the count variable, i.e. that the probability of having zero is equal to one for some observations. Lambert (1992) proposed the zero inflated Poisson model, ZIP, to deal with the situation in which a simple Poisson model is not enough to fit the data because of overdispersion and for which there are observations which always have zeros. In her paper, Lambert (1992) describes an experiment conducted in AT&T Bell laboratories to study the number of defects in soldered components. The occurrence of those defects has a probability nearly equal to zero when the equipment is properly aligned, and because lots of pieces are not defective there is an excessive zero counts, which fits the requirements of the ZIP model.

This paper deals with a problem in which the presence of zeros or the excess zeros in the random dependent variable is just the result of not having patents in a given place, in this case in a given county. It is, however, feasible that in any county the probability of having a positive count of patents is greater than zero¹⁷. This invalidates the assumption of the ZIP model.

An alternative that may be more suitable for the problem in question is the approach proposed by Mullahy (1986) known as the Hurdle Regression Model, HRM. The model splits the analysis in two parts, one dealing with the zeros and the other dealing with the truncated part after excluding the zeros. The latter part is what previous research is mainly focused on, as the treatment of the importance of the zeros is not present.

¹⁷ Unless, there is no population for the county, which is not true in this case.

HRM starts by considering the dichotomous part modeling a Logit or probit function for the presence/non-presence of innovations with π_i equal to the probability of not having patents in a place i :

$$Pr(y_i = 0|x_i) = \frac{\exp(x_i\gamma)}{1+\exp(x_i\gamma)} = \pi_i \quad (4.1)$$

Nonzero counts occur when we pass the hurdle with probability $(1 - \pi_i)$ such that:

$$Pr(y_i|x_i) = Pr(y_i|y_i > 0, x_i) = (1 - \pi_i), \text{ for } y_i > 0. \quad (4.2)$$

In the case of count models, depending on the diagnostics tests, the estimation can be performed either by Zero Truncated Poisson, ZTP, or Zero Truncated Negative Binomial, ZTNB. Note that the separability of the likelihood function allows for the estimation of the two models. This property is used to formulate a different approach to the analysis of innovation patterns.

In this case, the dependent variable has these properties but, as we need to model the intensity of the innovation, it is very likely that the bigger economies register more patents, so we need to normalize by county size. To this end, we model the per capita number of patents such that equation 4.1 accounts for the probability of having per capita patents equal to zero. Equation 4.2 will deal with the rest of the distribution, for positive numbers of per capita patents. Note that this new variable is no longer a count variable, so instead of a Poisson or a negative binomial we are using a truncated normal distribution. For this reason the model to estimate could be termed a Limited Dependent Hurdle Regression Model, LDHRM.

In this case the variable y_i follows the distribution given by:

$$Pr(y_i|x_i) = \begin{cases} \frac{\exp(x_i\gamma)}{1+\exp(x_i\gamma)} & ; y_i = 0 \\ Pr(y_i|y_i > 0, x_i) & ; y_i > 0 \end{cases} \quad (4.3)$$

For the positive counts the truncated normal distribution can be described as:

$f(y_i|y_i > c, x) = \frac{f(y_i|x_i)}{1-F(y_i>c|x_i)}$ where c is a constant that imposes the truncation threshold.

Given that y_i is truncated at a value equal to c , the moments of the distribution are affected such that:

$$E(y_i|y_i > c) = \mu + \sigma\lambda(\alpha) \quad (4.4)$$

Where $\alpha = (c - \mu)/\sigma$ and $\lambda(\alpha) = \phi(\alpha)/(1 - \Phi(\alpha))$

$\lambda(\alpha)$ represents what is called the inverse Mills ratio, in which the term in the numerator is the pdf of a standard normal variable, and the denominator is the cdf for such variable.

The variance in this case is represented as follows:

$$var(y_i|y_i > c) = \sigma^2[1 - \delta(\alpha)] \quad (4.5)$$

Where $\delta(\alpha) = \lambda(\alpha)[\lambda(\alpha) - \alpha]$

It is clear that the standard Ordinary Least Squares, OLS, model does not yield desired results as the coefficients will be biased. However, starting with this framework we can translate this formulation into the truncated regression model. Note that the positive counts part of the distribution is modeled in the following fashion:

$$y_i = \beta'x_i + \varepsilon_i, \text{ with the error term } \varepsilon_i \sim N(0, \sigma^2).$$

This results from a normal distribution for y_i with the following parameters:

$$y_i|x_i \sim N[\hat{\beta}x_i, \sigma^2] \quad (4.6)$$

Using the properties of the moments of the distributions presented in equations 4 and 5, it can be shown that for the truncated dependent variable (Greene, 2007) the expected value is equivalent to:

$$E[y_i|y_i > c] = \hat{\beta}x_i + \sigma \frac{\phi\left(\frac{c-\hat{\beta}x_i}{\sigma}\right)}{1-\Phi\left(\frac{c-\hat{\beta}x_i}{\sigma}\right)} \quad (4.7)$$

From this expression it is clear that there is a non-linear relation between the conditional mean of y_i and the parameters to estimate. A simplified version of this nonlinear estimation is as follows:

$$E[y_i|y_i > c] = \hat{\beta}x_i + \sigma \frac{\phi(\alpha_i)}{1-\Phi(\alpha_i)}, \text{ where } \alpha_i = \frac{c-\hat{\beta}x_i}{\sigma}$$

Then it is possible to simplify the previous expression in terms of the inverse Mills ratio, such that the estimation to perform is reduced to:

$$E[y_i|y_i > c] = \hat{\beta}x_i + \sigma\lambda(\alpha_i) \quad (4.8)$$

Note the difference with the simple OLS model where the expected value of y_i is equal to: $E[y_i|x_i] = \hat{\beta}x_i$.

Finally, it is assumed that y_i follows an homoskedastic normal distribution and for the sake of this assumption to be more plausible, a logarithmic transformation is recommended for y_i (Wooldridge, 2002). In any case, as this is a monotonous transformation applied to the dependent variable, the parameters that optimize the likelihood function will be the same.

4.5. Limited Dependent Hurdle Regression Model, LDHRM, Results.

The first approach taken here to tackle this problem in question is the estimation of a Hurdle Regression Model, LDHRM. The assumption behind this type of model is that there are actually two processes governing the behavior of the count variable, one for the zeros and other for the nonzero counts or one that models the hurdle that is to get past before being able to obtain positive values in the count variable modeled.

This estimation combines two models: one to predict the zeros using a binary model, usually a logistic form, with a categorical dependent variable equal to one when there are zero counts in the dependent variable and equal to zero when the dependent variable is greater than zero. The second model takes the form of a truncated normal regression such as the one presented in equation 4.6. For this exercise the results are shown in Table 5.

For the sake of comparison, column 1 shows the results of an Ordinary Least Squares, OLS. Note that the results of such model differ with respect to the other models in terms of the sign and significance of the coefficients. The coefficient for specialization is not significant and the coefficient for competition index is significant at the 5% level. Another critical problem with the OLS applied to this data is that, when fitting the data to the full set of observations, i.e. the zeros and the positive counts, the OLS model predicts negative values for the dependent variable, a result that is inconsistent or not possible. This is not the case when treating this problem with the LDHRM.

In the second column, the results for the Logit model shows a significant coefficient on the Herfindahl-Hirschman index for specialization. This means that more specialization in a given place is associated with a greater probability of not developing innovations. In other words, the more diversity, the more probability of overcoming the hurdle of not registering patents. This finding is in line with the hypotheses stated by Jacobs (1969) as it means that more diversity is associated to the birth of new ideas that eventually become a patentable innovation.

Table 5. Limited dependent hurdle regression model for patent intensity, 2000

	OLS Y= (per capita patents)	Logit (Y=1 if patents=0)	Truncated Y=Log(per capita patents), for patents>0
HHI (specialization)	-2.911 [1.801]	1.389* [0.552]	-0.608* [0.249]
CI (competition)	-1.326** [0.436]	0.188 [0.113]	0.053 [0.037]
College graduates, %	0.719*** [0.038]	-0.064*** [0.010]	0.049*** [0.003]
Average wage	0.794*** [0.074]	-0.055*** [0.017]	0.075*** [0.008]
Urban factor	1.009* [0.401]	-0.565*** [0.100]	0.118*** [0.033]
Prop. small firms	-0.038* [0.019]	-0.053*** [0.004]	-0.024*** [0.002]
Constant	-13.277*** [2.255]	4.169*** [0.508]	1.719*** [0.197]
N	3085	3085	1743
Log Likelihood	-1.22e+04	-1356.879	-1871.73

Note: * p<0.05, ** p<0.01, *** p<0.001. Standard errors in brackets. Robust standard errors reported.
Source: Author's calculation.

Along the same lines, being located in areas with a higher degree of urbanization, increases the odds of patenting. In this sense, the knowledge spillovers that are more easily spread in urban environments seem to be in effect. In this sense, Jacobs (1969) also argues that in the most diversified environments, as the ones present in urban areas, offer more fertile ground for generating new ideas and innovations, as a result of close contact between individuals, and in turn, the mix of ideas that originates from different sources, gives rise to new ideas. Rural areas on the contrary, have less face-to-face contact among people. As a result, the likelihood of a patented innovation is lower in those rural areas.

According to the results, a greater proportion of small companies is positively associated with the probability of not patenting. This can be understood as a relationship between higher odds of patenting to a smaller proportion of small firms in a given county. The economic intuition thus would suggest that it is in counties with higher proportion of big firms where new ideas are patented.

For the truncated part, the coefficient for specialization is also significant but the competition index, CI, is not. According to these results, it seems that the data provides support to Jacobs (1969) knowledge externalities hypothesis. Regarding the degree of competition the results do not support Porter's (1990) statement that the more competition, the higher the innovation rate.

Note, for instance, that the average wage is positively associated with the rate of patenting, which is consistent with the results of the Logit model, and so is the proportion of small establishments.

Another important conclusion from this analysis is that human capital, as proxied by the rate of college graduates in each county plays a role in the innovation patterns. In

the same sense, a higher average wage is associated to the presence of more intensive patenting behavior.

Finally, being located in an urban area increases the probability of developing innovations, which is consistent with the literature on city growth that posits that in cities people innovate more (Glaeser, 1992). Note that we are not dealing here with the interaction of people to link with the knowledge flows or knowledge spillovers; we are just analyzing the rate of innovation.

It is important to address theoretical issues regarding “urban externalities”, such as the claim by Schumpeter (1942) and Arrow (1962) who proposed that firms not only produced and gained new knowledge by the classic view of learning-by-doing, but they also gained new knowledge as an externality from other firms. Because such externalities represent a flow or an interaction between agents, the extent to which the “local knowledge infrastructure” allows the transfers of knowledge, will influence how new innovations appear. This may be the explanation for which the existence of research labs creates links from universities, research, and the private firms in a network that in most cases is fostered by those “urban externalities”.

Note that from this analysis, the main conclusion derived is that two generating processes are into play in the case of patenting patterns, and running a single model for the whole distribution of the variable is not defensible. In fact, the latter strategy yields results that are not consistent with the phenomenon analyzed.

An alternative to study the patterns of the innovation rates would be to model sub-regions for which the problem of the number of zeros does not affect the results of the estimations or alternatively, to concentrate on the positive counts of the innovations

variable. This is the alternative taken by Anselin *et al.* (1997) or O’ hUallachain and Lee (2010), which set out to explore the spatial autocorrelation effects on patenting rates.

Note that so far we have not dealt with the spatial nature of the data: spatial autocorrelation or spatial heterogeneity have not been considered in the modeling strategy. In the next section models are estimated using the same covariates as those used in the LDHRM model considering the presence of spatial heterogeneity by means of a Geographically Weighted Regression, GWR. This type of regression considers specifically the location of each observation in the sample and tests for the presence of spatially varying relationships. This alternative seems to be more valuable as, instead of adjusting for the bias that causes the omission of the spatial autocorrelation, the spatially varying coefficients help understand that the territory is not homogeneous and that, in some parts of it, processes may differ in terms of specialization or human capital relation to economic structure. For this reason, understanding how these relations change throughout space is a relevant issue.

4.6. Spatial Heterogeneity in Innovation Patterns

As we have seen in the previous maps of spatial distribution of innovations (Figure 14), there seems to be some spatial regimes where the zeros are concentrated and regimes of high intensity in innovative activity. This may suggest that the estimation of a global model may yield different results if different sub-regions are considered. Duranton and Puga (2001) study the role of diversified cities in fostering innovation; those diversified cities boosting innovations were called nursery cities. These authors claim that both specialized and diversified cities are important in a system of cities and the system of

cities may respond differently to specialization and competition. The question is if innovations from nursery cities respond differently to specialization and competition and other attributes measuring the structure of the economies.

Geographically Weighted Regression, GWR, provides a framework to test for spatially varying coefficients, and study how different phenomena are manifested differently depending on the local economies analyzed (Fotheringham *et al.*, 1998). The basic framework of GWR is very similar to Kernel regression in that it takes a spatial window to run local models for each observation, using the observations in the spatial window. Because there are spatial decay functions governing the process relations between sample units, not all observations are going to have the same effects everywhere. To operationalize this decay function the GWR employs different weighting schemes.

The main idea with this model may be better understood by starting with the simple OLS regression in which the vector of parameters is given by:

$$\hat{\beta} = (X'X)^{-1}X'y \quad (4.9)$$

GWR considers that the parameters vary as a function of the coordinates (u, v) of the observations so that the estimation is adjusted or weighted by $W(u_i, v_i)$:

$$\hat{\beta} = (X'W(u_i, v_i)X)^{-1}X'W(u_i, v_i)y \quad (4.10)$$

Assuming a Gaussian weighting scheme the matrix W will have entries i, j given by:

$$w_{ij}(u_i, v_i) = \exp \left[-\frac{1}{2} \left(\frac{d_{ij}}{b} \right)^2 \right] \quad (4.11)$$

Where d_{ij} is the distance between the observation in question, i , and some other observation j within a bandwidth of length b . The bandwidth is chosen arbitrarily setting a threshold cut or by minimizing the Means Squared Error, MSE, to have an adaptive bandwidth. The latter is more suitable for this study. This is due to the fact that choosing a fixed bandwidth will tend to include a greater number of counties in the East -as they are smaller in size- compared to the number that will be considered with the same bandwidth in the western part of the US.

For the empirical part, a sample of patents in 2000 is used, the latest year with most innovation intensity. I test again for the same relations that were used in LDHRM model. Table 6 shows the estimation of a global model, using OLS for the whole area, as well as the estimation of the locally weighted regression. Because the number of innovations will vary with the size of the local economies, this variable is normalized by the population in each county.

According to the results, only average wage and the proportion of college graduates show results for the local coefficients that are similar in terms of the sign to the global ones. These two variables had the expected coefficient, the higher the average wages the more incentives to innovate, and there are more innovations in counties where higher wages are paid.

In Table 6 it is also possible to identify that along the distribution of coefficients, the ones closer to the global estimations is the column corresponding to the median coefficients, but the rest of them vary significantly. If this had not been the case, estimating a locally weighted regression and a global regression would yield practically

the same results. As this is not the case, a detailed analysis of the results throughout all the geographic area under study will be provided.

Table 6. Distribution of parameters from GWR model

	Global	Min.	1stQu.	Median	3rdQu.	Max.
HHI (specialization)	-2.911	-26.490	-5.333	-2.552	0.652	31.630
CI (competition)	-1.326**	-6.451	-1.068	-0.346	0.423	2.219
College graduates, %	0.719***	0.163	0.461	0.656	0.873	1.511
Average wage	0.794***	0.055	0.517	0.632	0.960	2.665
Urban factor	1.009*	-6.014	-0.879	0.608	1.709	5.871
Prop. small firms	-0.038*	-0.305	-0.043	-0.022	0.020	0.112
Intercept.	-13.277***	-53.500	-21.680	-14.370	-7.455	-0.033

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Locally weighting function: Gaussian kernel. Bandwidth set to an adaptive quantile: 0.035, which corresponds to about 106 of 3085 counties in each local regression.
Source: Author's calculation.

Figure 15 displays the estimated local parameters for the independent variables. As shown, the coefficients range from negative to positive values. In other words, the relation of the urban externalities, human capital and the economic structure, to the innovation patterns, is better described by a varying coefficients model, than for a single model of average effects.

Note that at the aggregate level, the specialization index is not significant. This finding is equivalent to saying that, on average, the marginal effect of this factor on the dependent variable is equal to zero. This is not what the local estimation with the GWR shows, where there are indeed areas where the coefficient is not significant, but there are others where this factor does have an influence over innovation intensity.

It is interesting to note how specialization is negatively correlated with innovation rates in the states of New England, New Jersey and part of New York and Pennsylvania. In contrast, this relation is the inverse in Midwest states. These findings may be the result

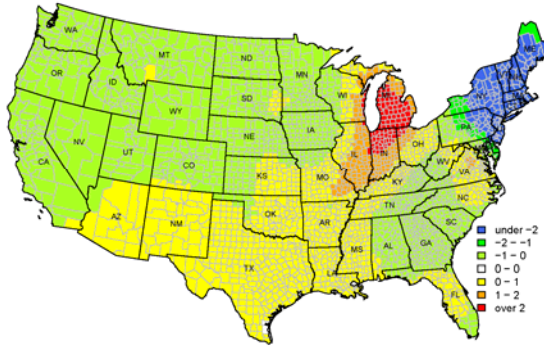
of changing patterns of specialization or diversification as well. This is not surprising if it is taken into account that from these two regions it has been noted that, for instance, Washington D.C. and New York are among the most specialized economies of the high-tech metropolitan areas. On the contrary, Chicago and Minneapolis are among the most diversified ones (Markusen and Yu, 2006).

As we have mentioned, for some of the coefficients, the relation is not statistically significant, but this result also changes throughout space. Because of this, it is also interesting to focus on the statistics that allows us to identify the areas for which each coefficient is significant in the GWR model. Using, for instance, the t -statistic for each variable and county, we are not only assessing the direction of the relation (sign of the coefficients) but also the statistical significance. ANNEX D displays the results for the t -statistics for each variable in the model.

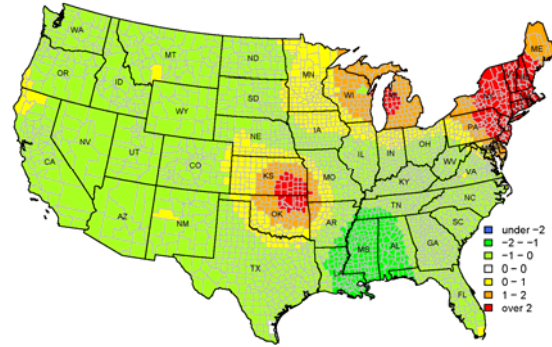
ANNEX D reveals that vast regions show significant coefficients and different signs for most of them. In fact, only the coefficients for the proportion of college graduates and average wage show a consistent sign and significance throughout the country. This means that probably it is the variables related to human capital that matter the most for innovation rates.

Figure 15. Spatial distribution of coefficients from GWR estimation.

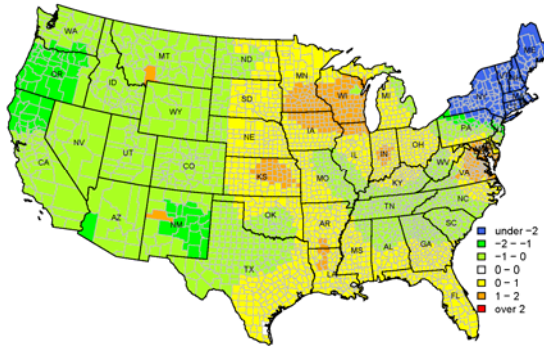
A. HHI (specialization)



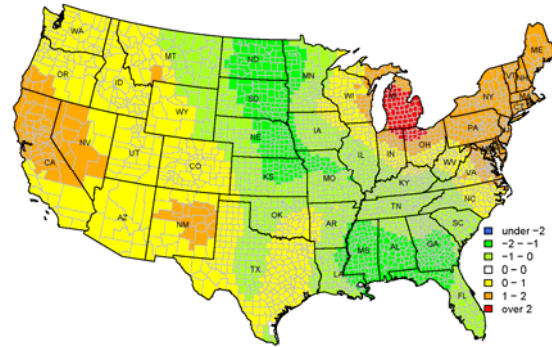
B. CI (competition)



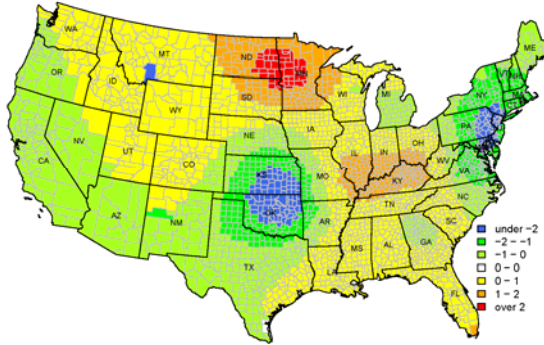
C. Proportion college graduates



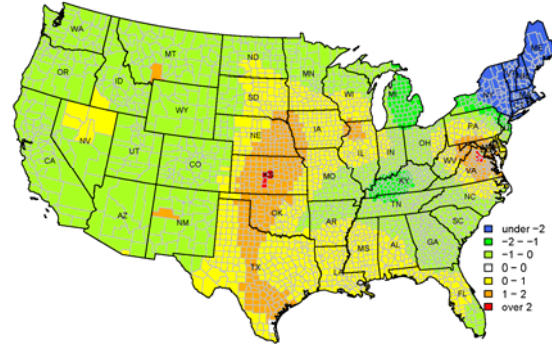
D. Average wage



E. Urbanization degree



F. Proportion small firms



Source: Author's calculation.

For the case of the specialization index, the hypothesis that more specialization yields more innovation (Marshall, 1920), is supported mainly by the data for the Midwest. This is rather intriguing as this region is found to have the most diversified metropolitan areas (Markusen and Yu, 2006). The same concern applied to the north-

eastern part of the country, where the results support better the ideas of Jacobs (1969) in regards to the economic diversity as an engine of the innovation process, and this same region is said to have the metropolitan areas with the highest degree of specialization. Notwithstanding, those areas seem to be atypical observations within their regional context, e.g., the fact that these atypical areas are located in Midwest and Northeast regions, does not make those regions as a whole, the most diversified or specialized ones within the country.

The question is then, is the assumption of spatial stationarity (constancy of coefficients) a justifiable one? What we are learning from this empirical evidence is that the relation of the explanatory variables with the innovation intensity is not constant throughout space and that the assumption of spatial stationarity is not plausible. This finding provides the rationale for analyzing local economies more in depth rather than the country as a whole, as a great deal of the previous research has done.

4.7. Discussion

This paper has addressed the extent to which innovation is affected by the structure of the economy in terms of the industrial specialization, diversity and competition. Innovation is proxied by the per capita patents assigned to US firms or inventors. Different theories of the relationship between innovation and regional economic structure have motivated this work. Those theories examine how characteristics of a regional economy at the county level in the US affect production of new knowledge or innovation. Marshall's (1920) theory of specialization, Jacobs' (1969) theory of diversity, and Porter's (1990) theory of competition constitutes the grounds to examine

empirically the determinants of innovation. The paper examines if those three theories are supported by the data in the US.

The main conclusions from the study suggest that it is not Marshall's theory of specialization but Jacobs' theory of diversity that may be driving the innovation patterns in the US. The estimations also point to the existence of urban externalities that foster innovation as the degree of urbanization of the counties is positively correlated to the intensity of the patenting behavior.

What may be the driver for this type of result? This is a question that is important to address, making reference to theoretical issues such as the claim by Schumpeter (1942) and Arrow (1962) who proposed that firms not only produced and gained new knowledge by the classic view of learning-by-doing, but they also gained new knowledge as an externality from other firms. Because such externality represents a flow or an interaction between agents, the extent to which the "local knowledge infrastructure" allows the transfers of knowledge, will influence how new innovations appear.

Regarding the degree of competition the results do not support Porter's (1990) statement that the more competition, the more rate of innovation, as in the models the variable for the competition index turned out to be non significant.

The preliminary exploration of spatial heterogeneity suggests that it is justifiable to address the spatial heterogeneity in a model for innovation intensity. This reinforces the need for a model that captures that interaction between firms or local economies, and studies the spillover effects that may be shaping the process of innovation.

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ANNEX A. COINTEGRATION TESTS RESULTS

Table A.1. Lag order determination for the system of equations

Lag	Akaike	Schwarz	Hannan-Queen
1	68.16	69.86*	68.83*
2	68.88	72.28	70.21
3	69.01	74.09	71.00
4	68.78	75.56	71.44
5	68.36	76.84	71.69
6	66.59*	76.76	70.58

Note: A pre-sample period was used to keep the sample size constant every time we evaluated a new lag. Starred values show the minimum information criterion.

Source: Calculations of the author.

Table A.2. Selection of rank of Π and model for cointegration.

Ho	Ha	Model 2		Model 3		Model 4	
		Trace	critical value	Trace	critical value	Trace	critical value
Lag 1							
r=0	r>0	150.05	131.70	149.81	124.24	166.20	146.76
r=1	r>1	99.19*	102.14*	98.95	94.15	111.44	114.90
r=2	r>2	74.59	76.07	74.36	68.52	81.51	87.31
r=3	r>3	50.75	53.12	50.52	47.21	56.94	62.99
r=4	r>4	30.55	34.91	30.38	29.68	34.44	42.44
r=5	r>5	13.67	19.96	13.52	15.41	17.48	25.32
r=6	r=7	2.33	9.24	2.19	3.76	2.36	12.25
Lag 2							
r=0	r>0	107.15*	131.70*	106.48	124.24	118.68	146.76
r=1	r>1	70.56	102.14	70.29	94.15	82.01	114.90
r=2	r>2	46.48	76.07	46.24	68.52	56.64	87.31
r=3	r>3	26.98	53.12	26.74	47.21	32.85	62.99
r=4	r>4	13.65	34.91	13.50	29.68	16.77	42.44
r=5	r>5	7.02	19.96	6.88	15.41	8.36	25.32
r=6	r=7	2.52	9.24	2.46	3.76	2.68	12.25
Lag 3							
r=0	r>0	96.11*	131.70*	95.69	124.24	107.67	146.76
r=1	r>1	65.77	102.14	65.48	94.15	76.67	114.90
r=2	r>2	41.34	76.07	41.06	68.52	48.09	87.31
r=3	r>3	25.47	53.12	25.27	47.21	30.18	62.99
r=4	r>4	14.31	34.91	14.22	29.68	15.73	42.44
r=5	r>5	7.40	19.96	7.39	15.41	7.88	25.32
r=6	r=7	2.16	9.24	2.15	3.76	2.61	12.25
Lag 4							
r=0	r>0	95.01*	131.70*	94.14	124.24	105.84	146.76
r=1	r>1	59.52	102.14	58.76	94.15	69.90	114.90
r=2	r>2	37.72	76.07	36.99	68.52	43.93	87.31
r=3	r>3	24.01	53.12	23.38	47.21	28.57	62.99
r=4	r>4	14.74	34.91	14.11	29.68	16.45	42.44
r=5	r>5	7.19	19.96	7.14	15.41	8.29	25.32
r=6	r=7	2.83	9.24	2.79	3.76	3.80	12.25
Lag 5							
r=0	r>0	84.76*	131.70*	84.13	124.24	91.07	146.76
r=1	r>1	48.98	102.14	48.42	94.15	54.60	114.90
r=2	r>2	31.93	76.07	31.41	68.52	37.47	87.31
r=3	r>3	19.19	53.12	18.77	47.21	24.81	62.99
r=4	r>4	12.20	34.91	11.78	29.68	15.72	42.44
r=5	r>5	6.42	19.96	6.10	15.41	8.86	25.32
r=6	r=7	2.17	9.24	2.02	3.76	4.03	12.25
Lag 6							
r=0	r>0	81.87*	131.70*	81.20	124.24	108.18	146.76
r=1	r>1	52.36	102.14	51.81	94.15	65.39	114.90
r=2	r>2	32.40	76.07	32.17	68.52	43.43	87.31
r=3	r>3	17.65	53.12	17.43	47.21	26.55	62.99
r=4	r>4	8.27	34.91	8.09	29.68	12.42	42.44
r=5	r>5	3.00	19.96	2.82	15.41	6.56	25.32
r=6	r=7	0.79	9.24	0.64	3.76	2.01	12.25

Note: the calculated values are adjusted for the sample size according to the suggestion of Cheung and Lai (1993): we multiply the calculated values by $(T-Pk)/T$. Where T =# observations, P =#variables, k =lag length. Seasonal dummies included are centered, i.e., they sum up to zero over time, this condition guarantees that the presence of those deterministic variables do not affect the asymptotic distribution of the tests conducted under Johansen methodology. Starred coefficients show the point where we cannot reject H_0 and then we take the decision about r .

Source: Calculations of the author.

Table A.3. Maximum eigenvalue Test, λ_{Max} , for the number of cointegration vectors

Lags = 1						
Ho: r=	Model 2		Model 3		Model 4	
	Adjusted λ_{max}	Critical Value 95%	Adjusted λ_{max}	Critical Value 95%	Adjusted λ_{max}	Critical Value 95%
0	50.86	46.45	50.86	45.28	54.76	49.42
1	24.59*	40.30*	24.58	39.37	29.93	43.97
2	23.85	34.40	23.84	33.46	24.56	37.52
3	20.19	28.14	20.14	27.07	22.50	31.46
4	16.88	22.00	16.86	20.97	16.96	25.54
5	11.35	15.67	11.33	14.07	15.13	18.96
6	2.33	9.24	2.19	3.76	2.36	12.25

Source: Calculations of the author. Starred statistics show the point where Ho was not rejected.

ANNEX B. COINTEGRATION BETWEEN REGIONAL SUBMARKETS

Table B. 1. Unit root test results for wages by metropolitan area

	ADF	Phillips-Perron
Barranquilla	Stationary	Stationary
Bogotá	Non-stationary	Non-stationary
Bucaramanga	Non-stationary	Non-stationary
Cali	Non-stationary	Non-stationary
Manizales	Stationary	Stationary
Medellín	Non-stationary	Non-stationary
Pasto	Non-stationary	Non-stationary

Note: In all cases where we conclude non-stationarity in levels, the result for the first differences supports the existence of stationarity thus we can say that the series are I(1).

Source: calculations of the author.

Table B.2. Cointegration results by pair of cities

cities	Number of Cointe- gration vectors	Lags in VAR model	Model chosen by tests	Trace test		Maximum eigenvalue test	
				trace	Critical value	λ -max	Critical value
Bucaramanga- Bogotá	1	2	2	3.56	9.24	3.56	9.24
Cali-Bogotá	1	1	2	4.39	9.24	4.39	9.24
Medellín-Bogotá	1	6	2	2.99	9.24	2.99	9.24
Pasto-Bogotá	0	1-6	N.A.	N.A.	N.A.	N.A.	N.A.
Cali- Bucaramanga	1	1	3	7.33	12.25	7.32	12.25
Medellín- Bucaramanga	0	1-6	N.A.	N.A.	N.A.	N.A.	N.A.
Pasto- Bucaramanga	0	1-6	N.A.	N.A.	N.A.	N.A.	N.A.
Medellín-Cali	0	1-6	N.A.	N.A.	N.A.	N.A.	N.A.
Pasto-Cali	1	2	2	2.60	9.24	2.25	9.24
Pasto-Medellín	0	1-6	N.A.	N.A.	N.A.	N.A.	N.A.

Note: Manizales and Barranquilla were not included in the analysis because they are stationary series according to unit root tests. Model chosen equals 2 for a model where only a long run constant is included. Model chosen equals 3 also includes a linear trend in the series in levels. N.A. not applicable.

Source: calculations of the author.

Table B.3. Normality and autocorrelation tests

cities	Normality		Autocorrelation	
	Chi. sq	p-value	Chi. sq	p-value
Bucaramanga-Bogotá	4.44	0.35	78.85	0.04
Cali-Bogotá	3.79	0.44	63.36	0.43
Medellín-Bogotá	3.17	0.53	47.10	0.15
Pasto-Bogotá	N.A.	N.A.	N.A.	N.A.
Cali- Bucaramanga	1.89	0.76	60.26	0.54
Medellín- Bucaramanga	N.A.	N.A.	N.A.	N.A.
Pasto- Bucaramanga	N.A.	N.A.	N.A.	N.A.
Medellín-Cali	N.A.	N.A.	N.A.	N.A.
Pasto-Cali	9.12	0.06	52.40	0.68
Pasto-Medellín	N.A.	N.A.	N.A.	N.A.

Note: Manizales and Barranquilla were not included in the analysis because they are stationary series according to unit root tests. N.A. not applicable. Ljung-Box test for autocorrelation displayed.

Source: calculations of the author.

ANNEX C. WAGE EQUATIONS RESULTS.

Table C.1. Fixed effects for the main seven metropolitan areas, 1984-2009.

Dependent Variable: Log(hourly wage)	1984	1985	1986	1987	1988	1989	1990	1991	1992
Barranquilla	-0.025 [-0.02]	-0.148*** [-0.02]	-0.103*** [-0.02]	-0.118*** [-0.02]	-0.164*** [-0.02]	-0.160*** [-0.02]	-0.174*** [-0.02]	-0.195*** [-0.02]	-0.185* [-0.02]
Bucaramanga	0.044* [-0.02]	-0.099*** [-0.03]	-0.059** [-0.02]	0.012 [-0.02]	-0.069*** [-0.02]	0.005 [-0.02]	-0.034 [-0.02]	0.039 [-0.02]	-0.002 [-0.02]
Manizales	-0.192*** [-0.03]	-0.395*** [-0.04]	-0.276*** [-0.03]	-0.203*** [-0.03]	-0.178*** [-0.03]	-0.148*** [-0.03]	-0.229*** [-0.03]	-0.165*** [-0.03]	-0.218* [-0.03]
Medellín	0.037*** [-0.01]	0.026 [-0.01]	0.009 [-0.01]	0.049*** [-0.01]	0.033** [-0.01]	0.059*** [-0.01]	-0.019 [-0.01]	0.023 [-0.01]	0.014 [-0.01]
Cali	0.063*** [-0.01]	-0.050** [-0.02]	-0.032* [-0.02]	0.090*** [-0.01]	0.013 [-0.01]	0.042** [-0.01]	0.008 [-0.02]	0.099*** [-0.02]	0.011 [-0.02]
Pasto	-0.407*** [-0.04]	-0.347*** [-0.04]	-0.530*** [-0.04]	-0.428*** [-0.04]	-0.486*** [-0.04]	-0.471*** [-0.04]	-0.616*** [-0.04]	-0.588*** [-0.04]	-0.540* [-0.04]

* p<0.05, ** p<0.01, *** p<0.001

Source: Authors calculations based on DANE.

**Table C.1. Fixed effects for the main seven metropolitan areas, 1984-2009.
(Continued)**

Dependent Variable: Log(hourly wage)	1993	1994	1995	1996	1997	1998	1999	2000	2001
Barranquilla	-0.153*** [-0.02]	-0.166*** [-0.02]	-0.252*** [-0.02]	-0.238*** [-0.02]	-0.261*** [-0.02]	-0.292*** [-0.02]	-0.270*** [-0.02]	-0.246*** [-0.02]	-0.061 [-0.02]
Bucaramanga	0.060** [-0.02]	0.046 [-0.02]	-0.034 [-0.02]	0.015 [-0.02]	-0.057* [-0.03]	-0.101*** [-0.03]	-0.096** [-0.03]	-0.066* [-0.03]	0.03 [-0.02]
Manizales	-0.153*** [-0.03]	-0.250*** [-0.04]	-0.251*** [-0.04]	-0.248*** [-0.04]	-0.223*** [-0.04]	-0.285*** [-0.04]	-0.236*** [-0.04]	-0.189*** [-0.04]	-0.067 [-0.03]
Medellín	0.012 [-0.01]	-0.041** [-0.01]	-0.026 [-0.01]	-0.125*** [-0.01]	-0.046** [-0.02]	-0.097*** [-0.02]	-0.064*** [-0.02]	-0.019 [-0.02]	0.078* [-0.01]
Cali	0.084*** [-0.02]	0.017 [-0.02]	-0.014 [-0.02]	-0.094*** [-0.02]	-0.106*** [-0.02]	-0.099*** [-0.02]	-0.019 [-0.02]	-0.051** [-0.02]	0.058* [-0.02]
Pasto	-0.483*** [-0.05]	-0.606*** [-0.05]	-0.562*** [-0.04]	-0.507*** [-0.04]	-0.406*** [-0.05]	-0.451*** [-0.05]	-0.396*** [-0.05]	-0.389*** [-0.05]	-0.249 [-0.04]

* p<0.05, ** p<0.01, *** p<0.001

Source: Authors calculations based on DANE.

Table C.1. Fixed effects for the main seven metropolitan areas, 1984-2009.
(Continued)

Dependent Variable: Log(hourly wage)	2002	2003	2004	2005	2006	2007	2008	2009
Barranquilla	-0.126*** [-0.02]	-0.142*** [-0.02]	-0.107*** [-0.02]	-0.120*** [-0.02]	-0.117*** [-0.02]	-0.182*** [-0.02]	-0.158*** [-0.02]	-0.200*** [-0.02]
Bucaramanga	-0.021 [-0.02]	0 [-0.02]	0.018 [-0.02]	-0.078*** [-0.02]	0.029 [-0.02]	-0.023 [-0.02]	-0.063** [-0.02]	-0.03 [-0.02]
Manizales	-0.114*** [-0.03]	-0.092** [-0.03]	-0.087** [-0.03]	-0.121*** [-0.03]	-0.066* [-0.03]	-0.169*** [-0.03]	-0.111*** [-0.03]	-0.186*** [-0.03]
Medellin	0.044** [-0.01]	0.085*** [-0.01]	0.097*** [-0.01]	0.083*** [-0.01]	0.062*** [-0.01]	0.066*** [-0.01]	0.006 [-0.01]	-0.012 [-0.01]
Cali	0.042** [-0.01]	0.028 [-0.01]	0.063*** [-0.02]	0.084*** [-0.01]	-0.005 [-0.01]	0.045** [-0.01]	-0.014 [-0.01]	-0.046** [-0.01]
Pasto	-0.249*** [-0.04]	-0.206*** [-0.04]	-0.162*** [-0.04]	-0.299*** [-0.04]	-0.368*** [-0.04]	-0.338*** [-0.04]	-0.392*** [-0.04]	-0.350*** [-0.04]

* p<0.05, ** p<0.01, *** p<0.001

Source: Authors calculations based on DANE.

Table C.2. Fixed effects for the main thirteen metropolitan areas, 2001-2009.

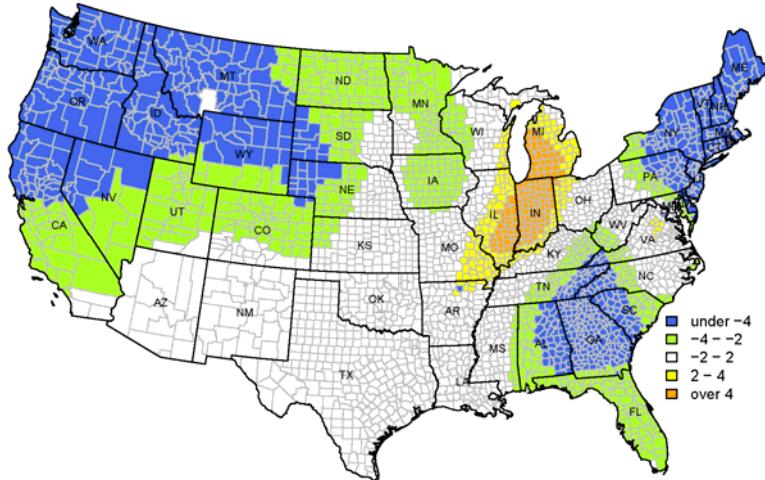
Dependent Variable: Log(hourly wage)	2001	2002	2003	2004	2005	2006	2007	2008	20
Barranquilla	-0.083*** [-0.02]	-0.151*** [-0.02]	-0.175*** [-0.02]	-0.136*** [-0.02]	-0.161*** [-0.02]	-0.157*** [-0.02]	-0.276*** [-0.04]	-0.200*** [-0.02]	-0. [-c]
Bucaramanga	0.006 [-0.02]	-0.047* [-0.02]	-0.034 [-0.02]	-0.012 [-0.02]	-0.120*** [-0.02]	-0.013 [-0.02]	0.079 [-0.04]	-0.108*** [-0.02]	-0. [-c]
Manizales	-0.090** [-0.03]	-0.141*** [-0.03]	-0.126*** [-0.03]	-0.117*** [-0.03]	-0.164*** [-0.03]	-0.107*** [-0.03]	-0.048 [-0.07]	-0.156*** [-0.03]	-0. [-c]
Medellín	0.056*** [-0.01]	0.02 [-0.01]	0.053*** [-0.01]	0.069*** [-0.01]	0.042*** [-0.01]	0.021 [-0.01]	0.095*** [-0.03]	-0.037** [-0.01]	-0. [-c]
Cali	0.035* [-0.02]	0.016 [-0.02]	-0.005 [-0.02]	0.034* [-0.02]	0.043** [-0.01]	-0.046*** [-0.01]	-0.091** [-0.03]	-0.058*** [-0.01]	-0. [-c]
Pasto	-0.272*** [-0.04]	-0.275*** [-0.04]	-0.241*** [-0.04]	-0.192*** [-0.04]	-0.345*** [-0.04]	-0.411*** [-0.04]	-0.464*** [-0.08]	-0.437*** [-0.04]	-0. [-c]
Cartagena	-0.176*** [-0.03]	-0.156*** [-0.04]	-0.106** [-0.03]	-0.178*** [-0.03]	-0.113*** [-0.03]	-0.143*** [-0.02]	-0.674*** [-0.06]	-0.197*** [-0.03]	-0. [-c]
Montería	-0.284*** [-0.05]	-0.301*** [-0.05]	-0.317*** [-0.05]	-0.239*** [-0.05]	-0.277*** [-0.04]	-0.392*** [-0.04]	-0.183* [-0.09]	-0.315*** [-0.04]	-0. [-c]
Villavicencio	-0.053 [-0.04]	-0.077* [-0.04]	-0.128** [-0.04]	-0.056 [-0.04]	-0.105** [-0.04]	-0.093** [-0.03]	-0.194* [-0.08]	-0.098** [-0.04]	-0. [-c]
Cúcuta	-0.032 [-0.03]	-0.046 [-0.03]	-0.168*** [-0.03]	-0.163*** [-0.03]	-0.221*** [-0.02]	-0.187*** [-0.02]	-0.120* [-0.05]	-0.151*** [-0.03]	-0. [-c]
Pereira	0.019 [-0.03]	0.001 [-0.02]	0.008 [-0.02]	0.046 [-0.03]	-0.028 [-0.02]	-0.004 [-0.02]	0.098 [-0.05]	-0.138*** [-0.03]	-0. [-c]
Ibagué	-0.113*** [-0.03]	-0.132*** [-0.03]	-0.141*** [-0.03]	-0.105*** [-0.03]	-0.193*** [-0.03]	-0.184*** [-0.03]	-0.044 [-0.06]	-0.224*** [-0.03]	-0. [-c]

* p<0.05, ** p<0.01, *** p<0.001

Source: Authors calculations based on DANE.

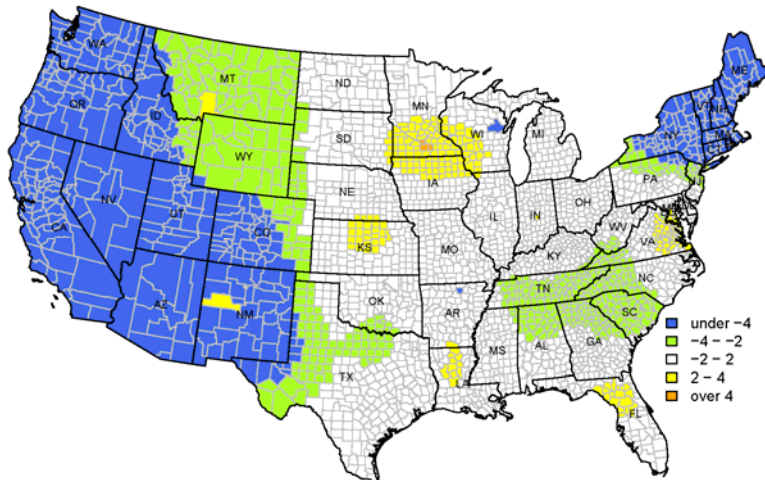
ANNEX D. SPATIAL DISTRIBUTION OF T-STATISTICS

Figure D.1. Spatial distribution of t-statistics of specialization index



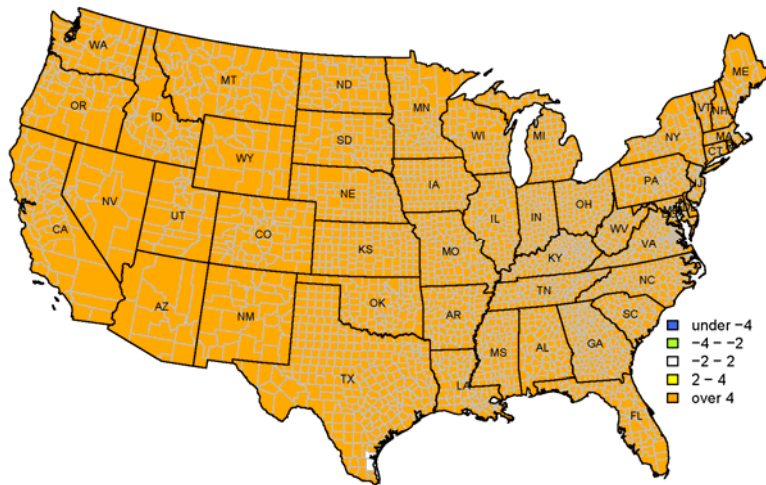
Source: Author's calculation.

Figure D.2. Spatial distribution of t-statistics of competition index



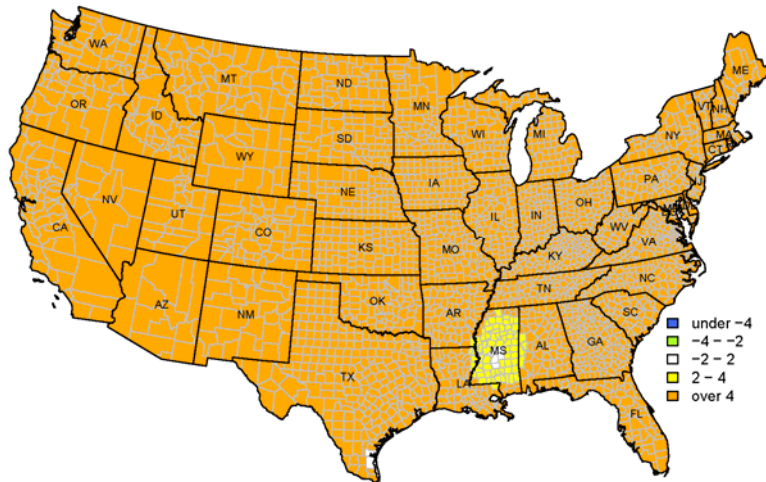
Source: Author's calculation.

Figure D.3. Spatial distribution of t-statistics of proportion of college graduates



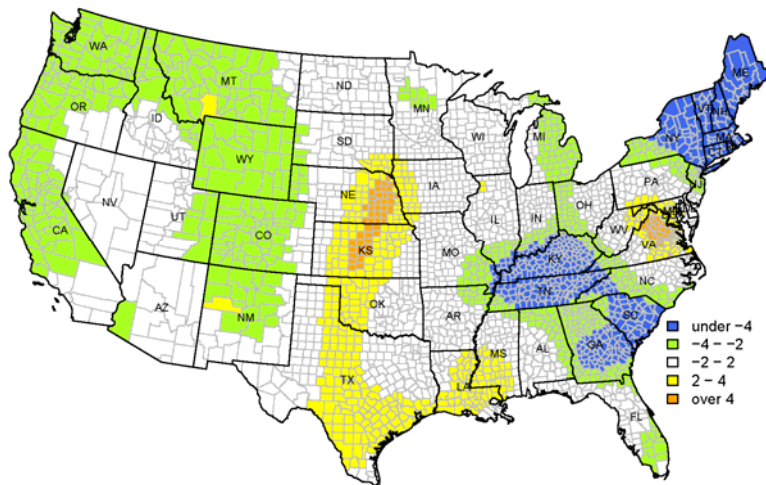
Source: Author's calculation.

Figure D.4. Spatial distribution of t-statistics of average wage



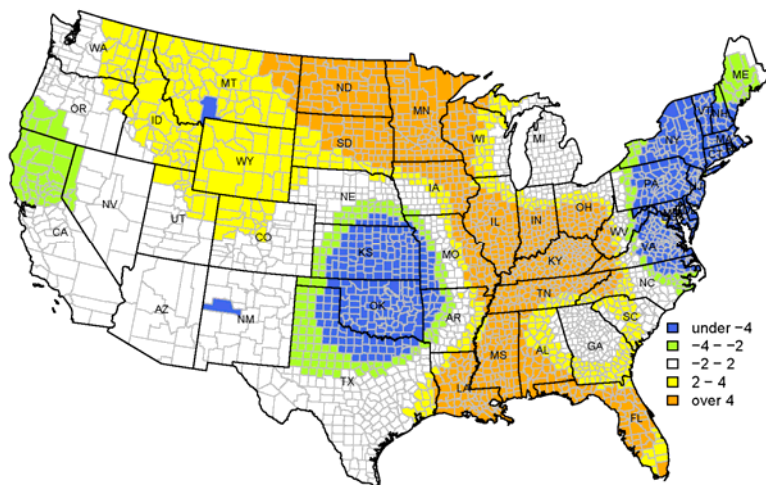
Source: Author's calculation.

Figure D.5. Spatial distribution of t-statistics of percentage of small firms



Source: Author's calculation.

Figure D.6. Spatial distribution of t-statistics of urban indicator variable



Source: Author's calculation.